ASURA 2012

Australasian Symposium on Ultrasound and Regional Anaesthesia

10-12 March, 2012

Sheraton on the Park, Sydney

New South Wales, Australia

www.asura2012.com.au

ASURA

Australasian Symposium on Ultrasound and Regional Anaesthesia

Coordinated by the Regional Anaesthesia Special Interest Group

ACECC

Anaesthesia Continuing Education Coordinating Committee

Convenor's Welcome

As the Convenor of ASURA 2012, I would like to welcome you to Sydney for what is an exciting programme of regional anaesthesia topics.

The application of ultrasound imaging has revolutionised and re-energised the practice of regional anaesthesia and we are fortunate to have an international faculty at the cutting edge of contemporary practice and teaching joining us. After an overview morning on Saturday the lecture programme is built around four themes; innovation and controversy, safety, practicality and teaching. As well as the lecture programme we are continuing the ASURA formula of small group teaching with the addition of masterclasses and focused discussion groups for those who have progressed beyond the basics.

Our large conference venue, Sheraton on the Park, has enabled us to host the whole meeting under one roof. In addition, Sheraton on the Park is well situated in central Sydney where delegates can meet with faculty, colleagues and friends during ASURA.

I look forward to meeting you all during the conference.

Dr Peter Hebbard

Convenor, ASURA 2012

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Speakers

Dr O'Donnell

Dr O'Donnell

Dr O'Donnell received his MB BCh BAO from Trinity College Dublin in 1997. Having spent three years working in emergency and respiratory medicine in Ireland, he entered anaesthesia specialist training in 2000 at Beaumont Hospital Dublin. He was accepted onto the National Specialist Registrar training scheme in 2002, became a Fellow of the College of Anaesthetists of Ireland (FCARCSI) in 2003 and was awarded the degree of MSc in Anaesthesia with first class honours in 2007. Also in 2007, he was awarded the Certificate of Completion of Specialist Training (CCST). In 2010 he was awarded the degree of MD with commendation by University College Cork, for his research on the role of ultrasonography in axillary brachial plexus block.

He was appointed to the position of consultant anaesthetist at BreastCheck and Cork University Hospital, and Honorary Senior Lecturer at University College Cork in 2009. He is the current Honorary Secretary of the Irish Society for Regional Anaesthesia and the Director of the Cork Cadaveric Peripheral Nerve Block Course. His academic work includes original research into the role of Transversus Abdominis Plane block in analgesia following abdominal surgery and ultrasonography in axillary brachial plexus block. He has published on the topic of regional anaesthesia and acute pain, and ultrasonography in regional anaesthesia. His current research interests include the role of simulation in regional anaesthesia training and accreditation, and the role of innovative technologies in making regional anaesthesia safer and more accessible.

Brian is married to Fiona, and is the proud father of three children. He is a keen sportsman who currently plods around the world running marathons, and flounders his way through triathlon courses.

A/Prof Paul Bigeleisen

A/Prof Paul Bigeleisen

A/Prof Paul Bigeleisen is professor of anesthesiology and bioengineering at the Universities of Rochester and Maryland. He obtained his medical degree from the University of California at Davis. He completed his residency in anesthesiology at the Upstate Medical Center in Syracuse and a fellowship in pain management at Emory University. He is the author of 9 textbooks, 35 book chapters, 30 manuscripts and the recipient of 10 international awards for teaching and research. His current research interests are in applied anatomy and medical robotics.

Dr Gadsden

Dr Jeff Gadsden

Dr Jeff Gadsden is a staff anesthesiologist at St. Luke's-Roosevelt Hospital Center in New York, and the Director of the Regional Anesthesia Fellowship Program. He graduated with an M.D. in 1999 from Queen's University, Canada, and undertook training in anesthesiology at the University of Toronto and St. Luke's-Roosevelt Hospital in New York City. Dr. Gadsden holds fellowships with the Royal College of Physicians and Surgeons of Canada (Anesthesia) and the Australian and New Zealand College of Anaesthetists, and is board certified by the American Board of Anesthesiology. After working in both Canada and Australia, he decided to return to New York City to focus on his teaching and research interests, which include ultrasound-guided nerve blockade, the monitoring of regional anesthesia, ambulatory anesthesia and outcomes, and education. Dr. Gadsden has taught hands-on workshops in the U.S., Canada, Asia, Australia, and Europe, has co-authored multiple book chapters and peer-reviewed articles, and has lectured both nationally and abroad.

Dr Bedforth

Dr Nigel Bedforth

Dr Nigel Bedforth is a consultant anaesthetist at The Queen's Medical Centre, Nottingham, UK and have been developing our regional anaesthesia programme since my appointment in 2001. He supervises the local regional anaesthesia training modules and has set up a regional fellowship, which has been running for over five years.

He has seven years experience of performing ultrasound-guided regional anaesthesia; which he believes (when properly used) is the gold-standard technique for delivery of peripheral regional anaesthesia. He is a member of the UK Nerve Imaging Group (a specialist interest group within Regional Anaesthesia-UK), aiming to further education in ultrasound-guided techniques in the UK. They are developing a teaching website at ragbi.org and run courses around the country. He is a board member of Regional Anaesthesia UK. He has run workshops & delivered lectures at national and international meetings on ultrasound-guided regional anaesthesia and authored a number of articles on the subject. He is also an editor with the UK scientific journal 'Anaesthesia'.

Outside of work his main source of fulfilment is his family and of frustration his golf game!


Col. Buckenmaier

Colonel Chester 'Trip' Buckenmaier III, MD

Colonel Chester 'Trip' Buckenmaier III, MD is chief of the tri-service Defense and Veterans Center for Integrative Pain Management (DVCIPM). The organization is devoted to revolutionizing pain management throughout the continuum of care on the battlefield and at home. Under his leadership, this organization has established the acute pain medicine and regional anesthesia fellowship program at Walter Reed National Military Medical Center, the first military pain infusion system currently employed in Role 3 facilities, and published the first military textbook on battlefield pain management (Military Advanced Regional Anesthesia and Analgesia – Borden Institute). The DVCIPM has played a leadership role in the development of the Pain Task Force document and USAMEDCOM Comprehensive Pain Management Campaign Plan. Doctor Buckenmaier is an internationally recognized leader in acute pain medicine and the author of numerous peer reviewed articles on regional anesthesia and acute pain medicine. Recently Colonel Buckenmaier completed a deployment tour to Camp Bastion, Afghanistan with the British military, establishing the first acute pain service at a Role 3 medical facility.

Military awards include the military medicine 'A' designator, Legion of Merit, and Meritorious Service Medal (second award). COL Buckenmaier has also earned the Flight Surgeon Badge and Expert Field Medical Badge.


Dr Hocking

Dr Graham Hocking

Dr Graham Hocking has had an active interest in regional anaesthesia for 15 years and ultrasound for 11 years. He has published widely in the fields of regional anaesthesia and pain medicine. His current interests mainly focus around how we can best teach and assess skills in ultrasound guidance and those of needle visibility. He has lectured nationally and internationally on topics in regional anaesthesia and is a faculty member for NYSORA, ISSPS (Hong Kong), The University of Melbourne and previous ASURA meetings in addition to being the convenor of the Australian Regional Anaesthesia Cadaveric Ultrasound Seminars.

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Table of Contents

Knobs and Buttons

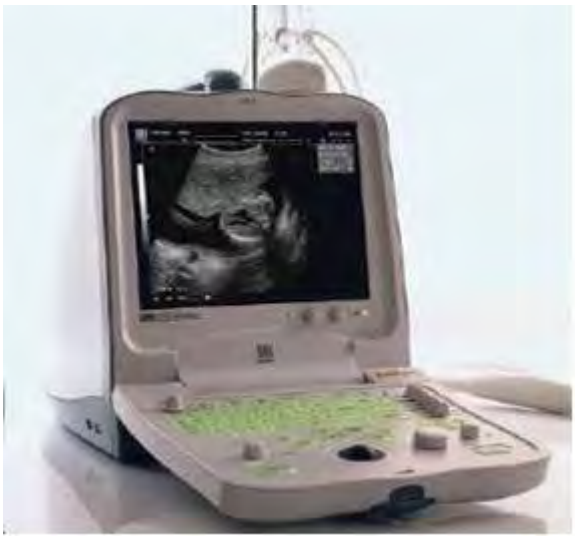
Dr. Wes Cormick **BMed BMedSc FRACP DDU**
Radiologist, Canberra

Understanding the basic functions of the ultrasound machine is vital to acquiring a good image. A good image is important to avoid:

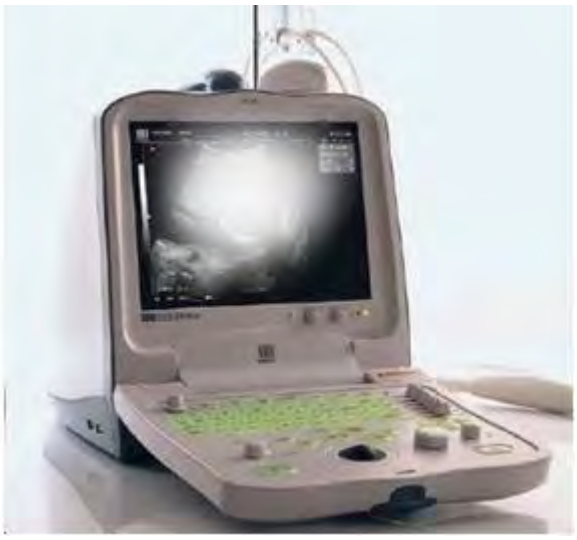
- needling a closely associated artery or vein
- missing the nerve
- needling into the nerve
- not being aware of normal variants like duplicated nerves

The monitor must be positioned to avoid reflection and light directed onto it.

The monitor must be kept clean and free of fingerprints, iodine and jelly.



A monitor without reflected light



Reflected light obscuring the screen

If you are working in a sterile field it is important to get your machine set up properly before you scrub up. This will avoid you having the break sterility and adjust the machine while you are working. It is a good idea to set up the machine on yourself before you get to work on the patient.

Knobs

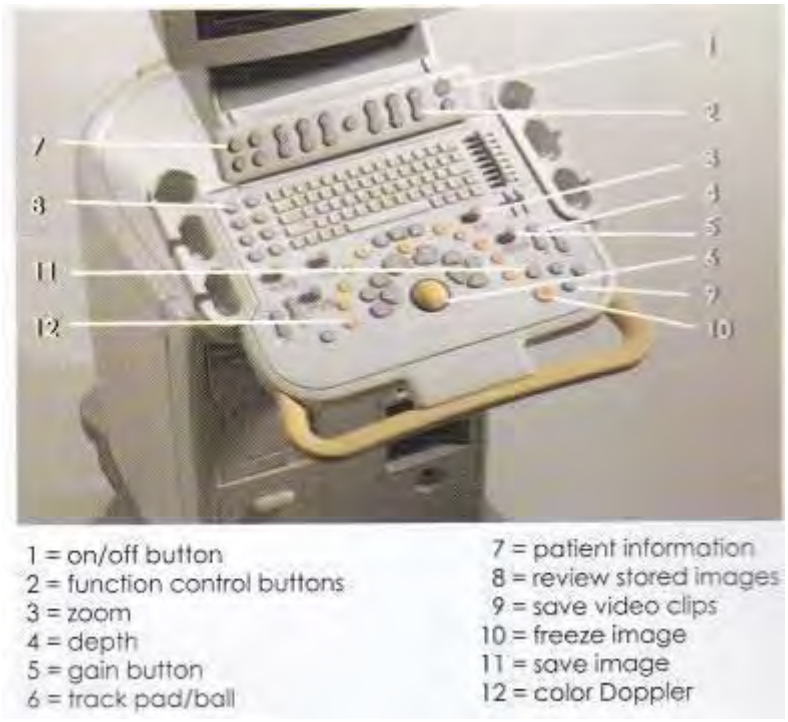


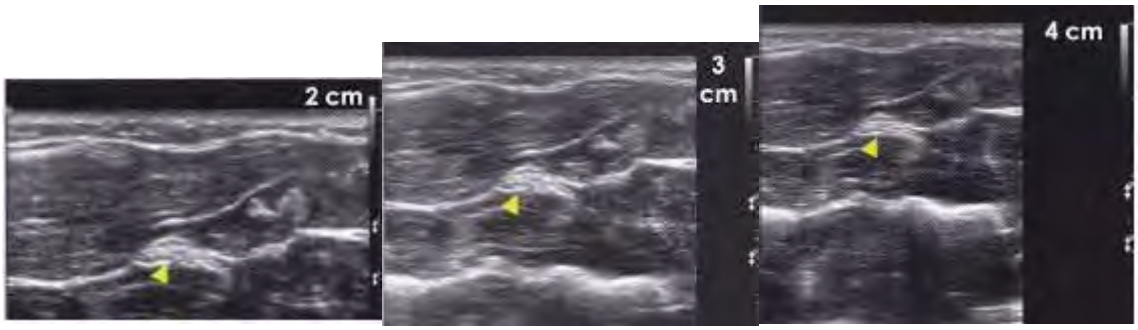
Image showing a typical keyboard layout

Adjust the following in order:

- Depth
- Focus
- TGC
- Zoom
- Gain
- Dynamic Range (contrast)

1. Depth

Depth settings should be set so that the target is comfortably seen

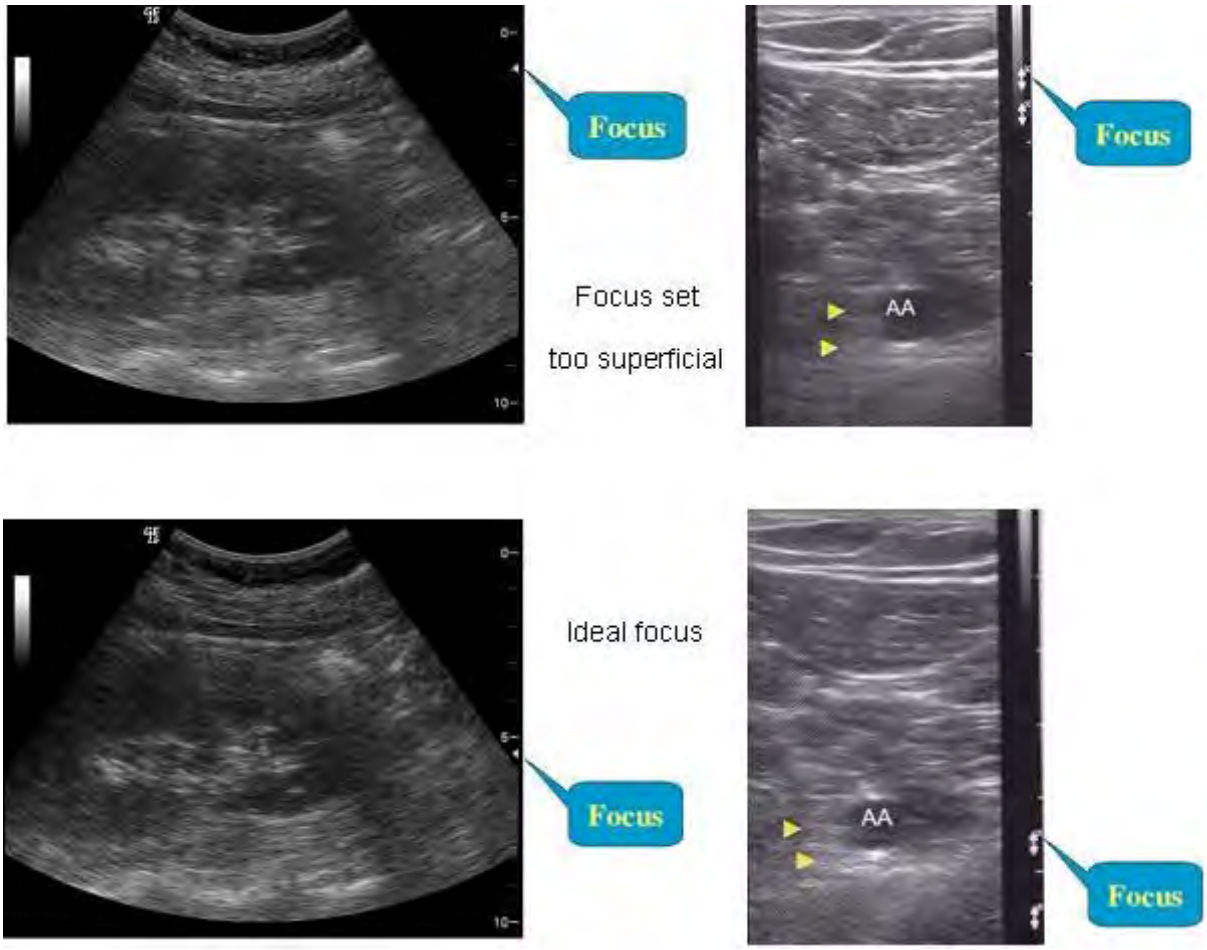


The Impact of the Depth Setting on Image Quality

The figures above illustrate how the image of the median nerve in the forearm (arrowhead) gets smaller and smaller as the depth is increased from 2 cm to 6 cm. It is important to select the appropriate depth setting (e.g. 2 cm in this case) according to the target nerve location.

2. Focus

The focus should be adjusted so the target is highlighted.

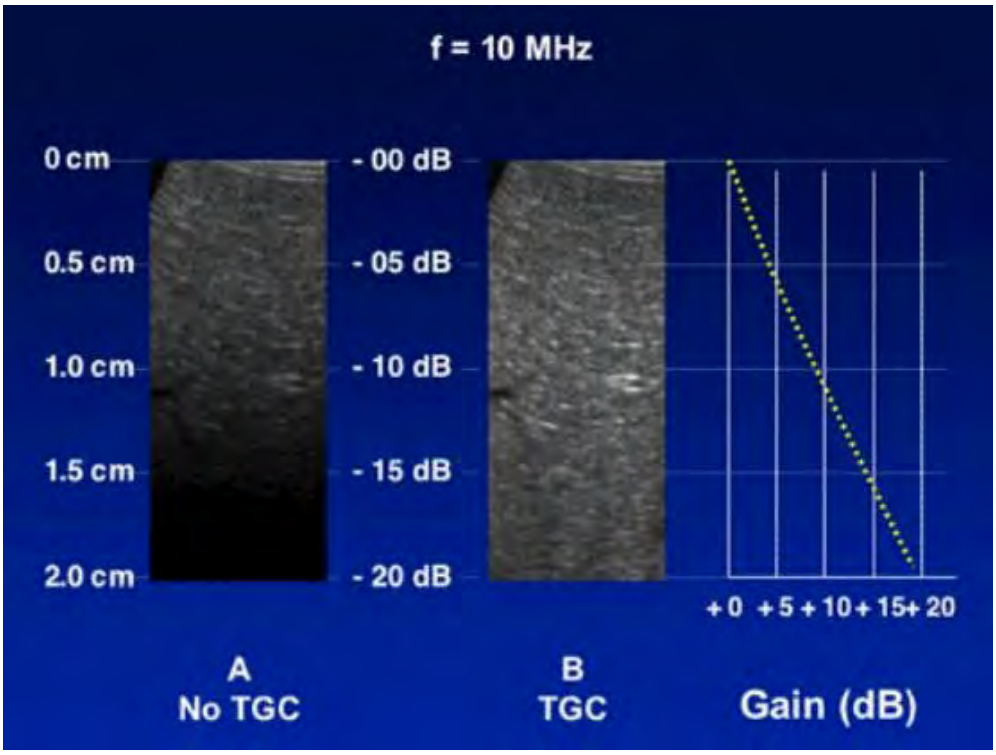


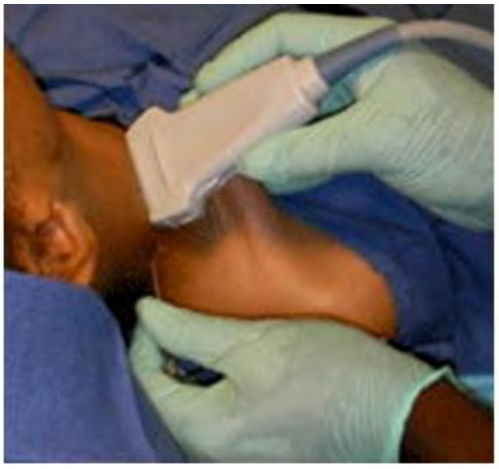
The focus or focal zones allow you to shape the ultrasound beam to be thinnest where you want it to be. If the beam is too wide at the target the beam width will include the needle and target in the same image even though they may be several mm apart.

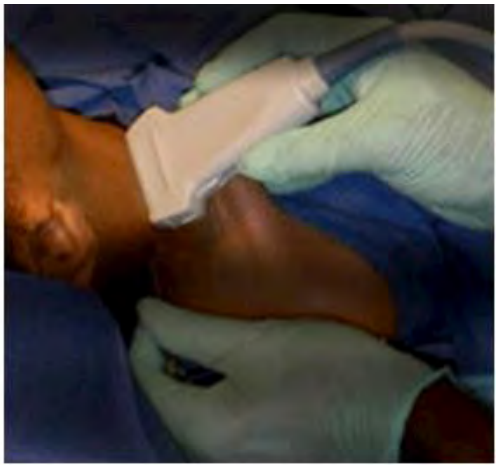
Beware of using too many focal zones which can slow down the display and may produce artefacts like a range ambiguity artefact through a cyst or vessel.

3. TGC

The TGC (Time gain compensation) allows you to enhance or decrease the signal from different depths. You can manipulate the TGC to decrease unwanted noise from the image such as near field reverberation, posterior enhancement, or bright echoes from deep bone or gas; all of which are distracting.



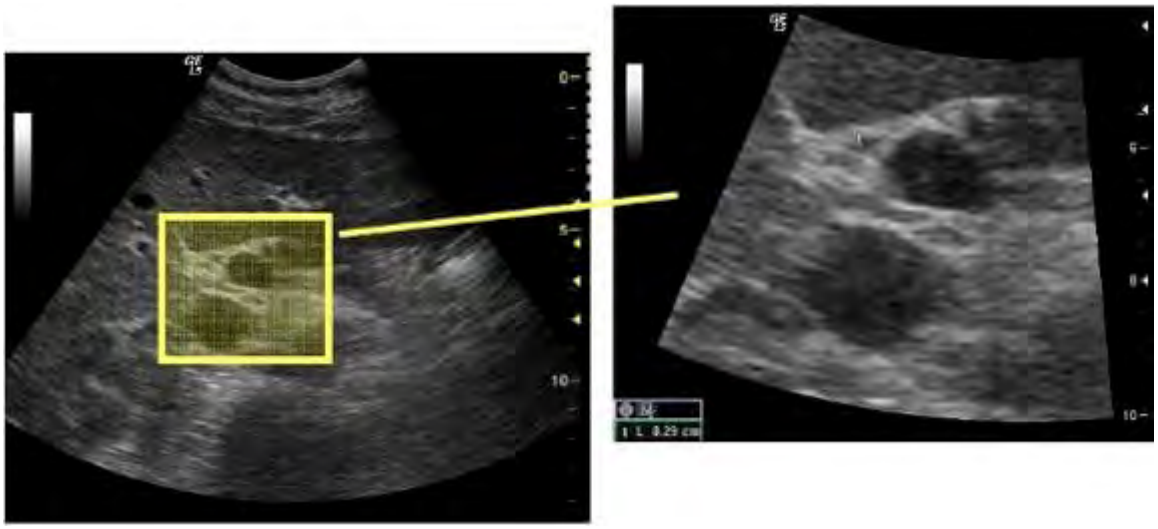




Normal TGC ***TGC adjusted to highlight image***

4. Zoom

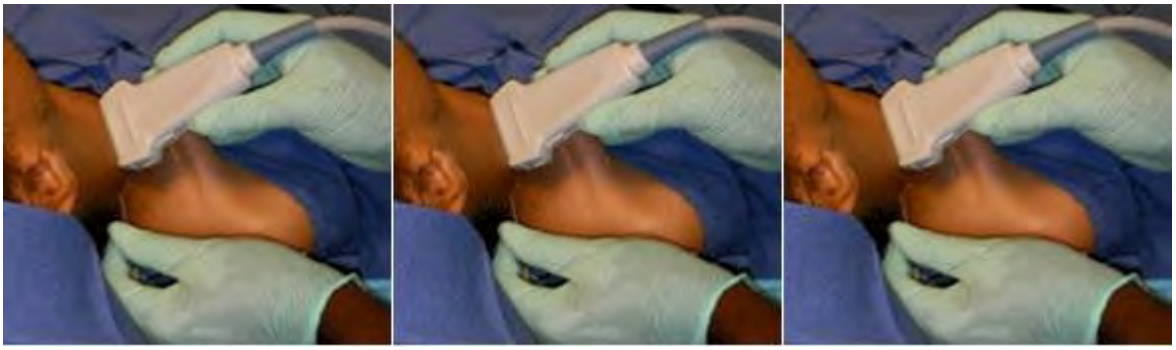
Zoom can enlarge the target area for you but you may lose the needle pathway from the skin so be cautious in its use.



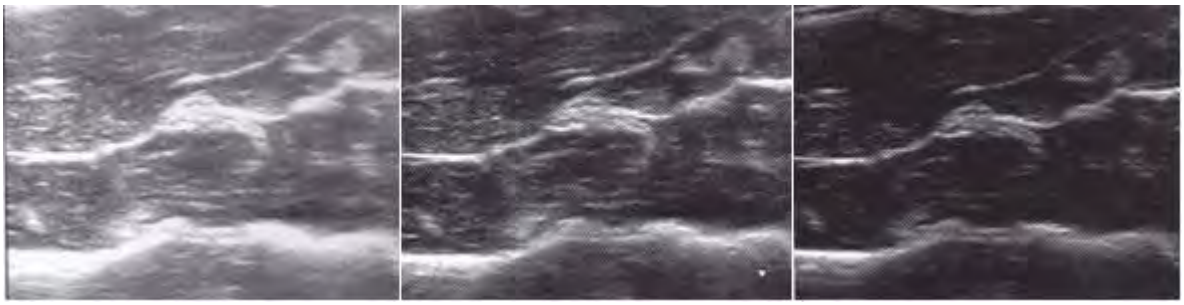
The effect of zoom on the target area

5. Gain

The gain button is responsible for the overall exposure on the image. A mistake is to try and improve the image by increasing the gain when the trick may be to decrease the gain.

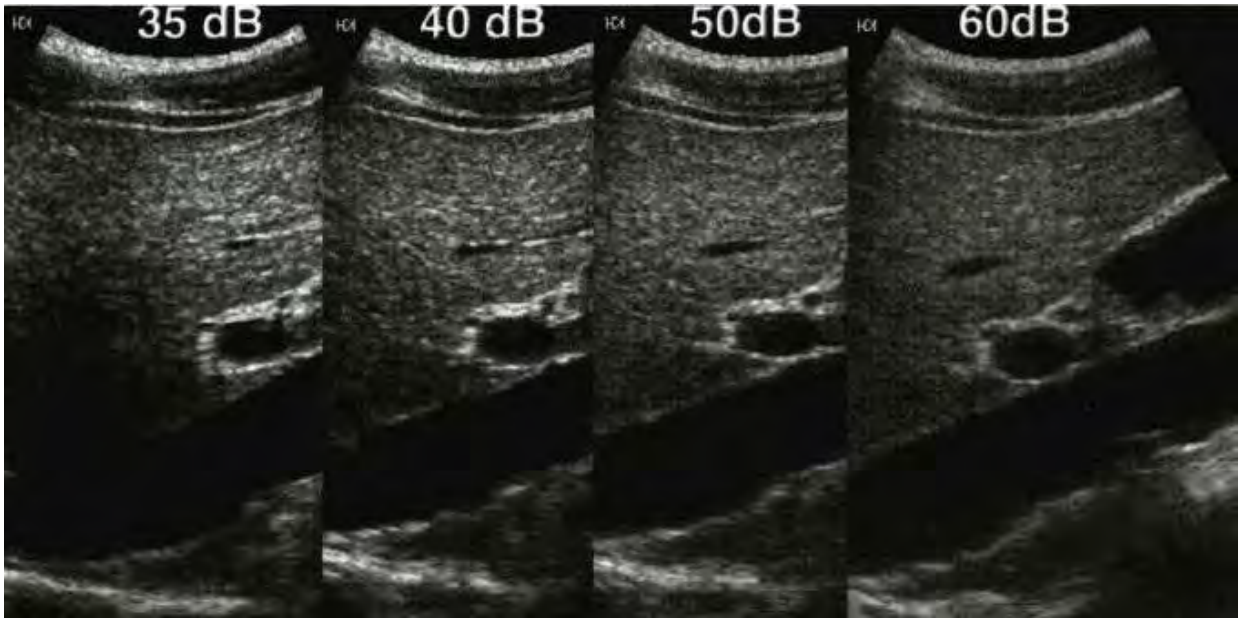


Too much gain **Normal** **Too little gain**



6. Dynamic Range

The ultrasound transducer must compress the wide range of returning amplitudes into a range that can be displayed to the user. The widest dynamic range permits the best differentiation of subtle differences in echo intensity and is the preferred setting for most of the time. The smaller ranges will increase conspicuousness of larger echo differences.

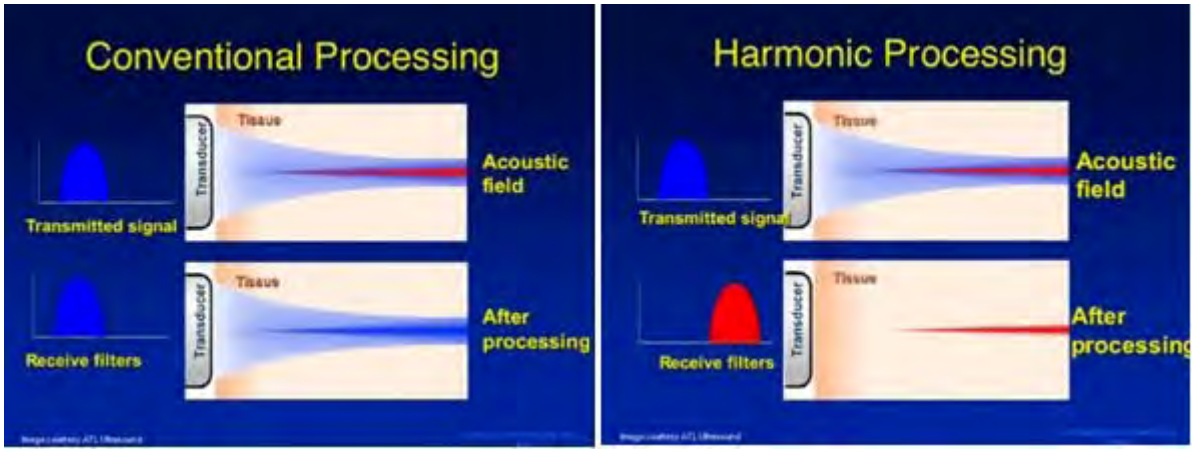


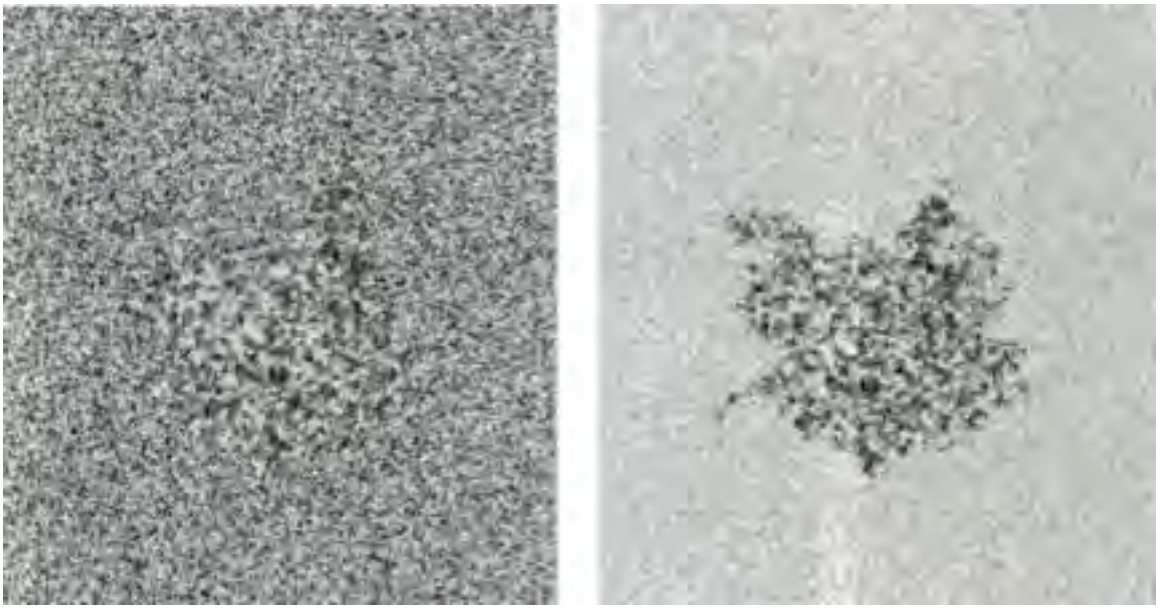
The effect of changing the dynamic range on image quality

Other Settings

Harmonic Imaging

If your machine is fitted with harmonics it enhances the ability to 'see' the needle tip and cleans up the image by reducing clutter and speckle artefacts.

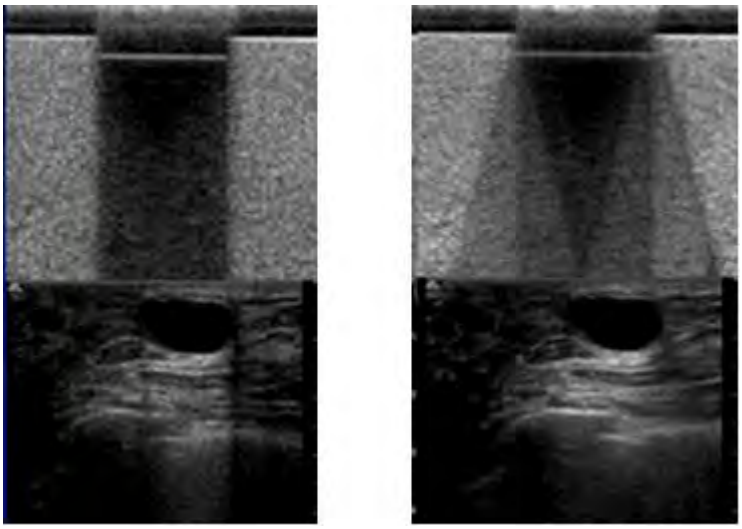




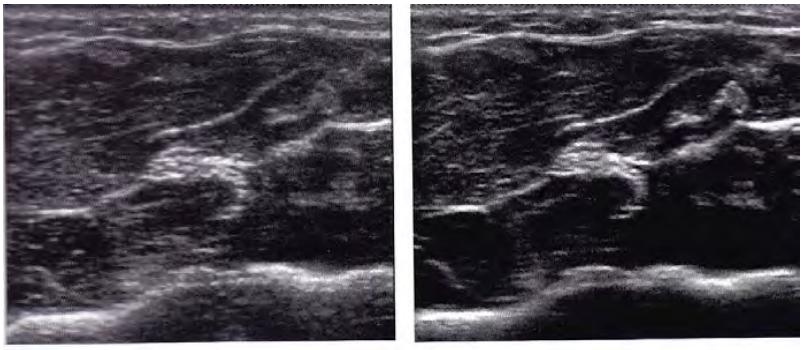
Reduced speckle

Compound Imaging

Compound imaging improves the image in the centre of the field of view. Thus it is important to ensure your target is in the centre and not at the edge of the field.



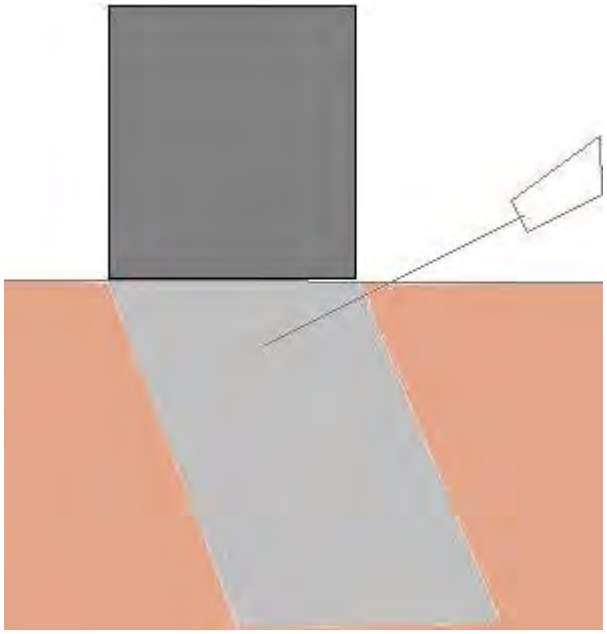
Field enhancement with compounding



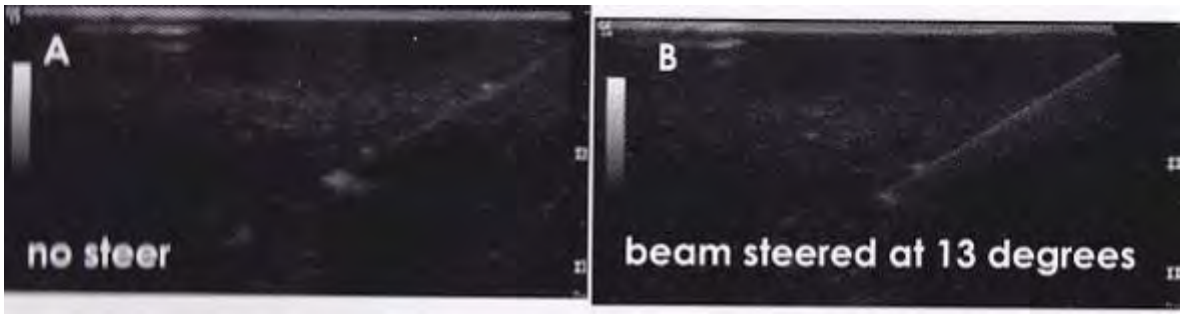
No Compound Imaging *Compound Imaging*

Beam Steering

Beam steering is fitted to some machines and improves the ability to 'see' the needle in in-line approaches. The closer the needle is to 90 degrees the sharper the image will be. It also allows you to visualise the needle before it actually moves under the transducer.



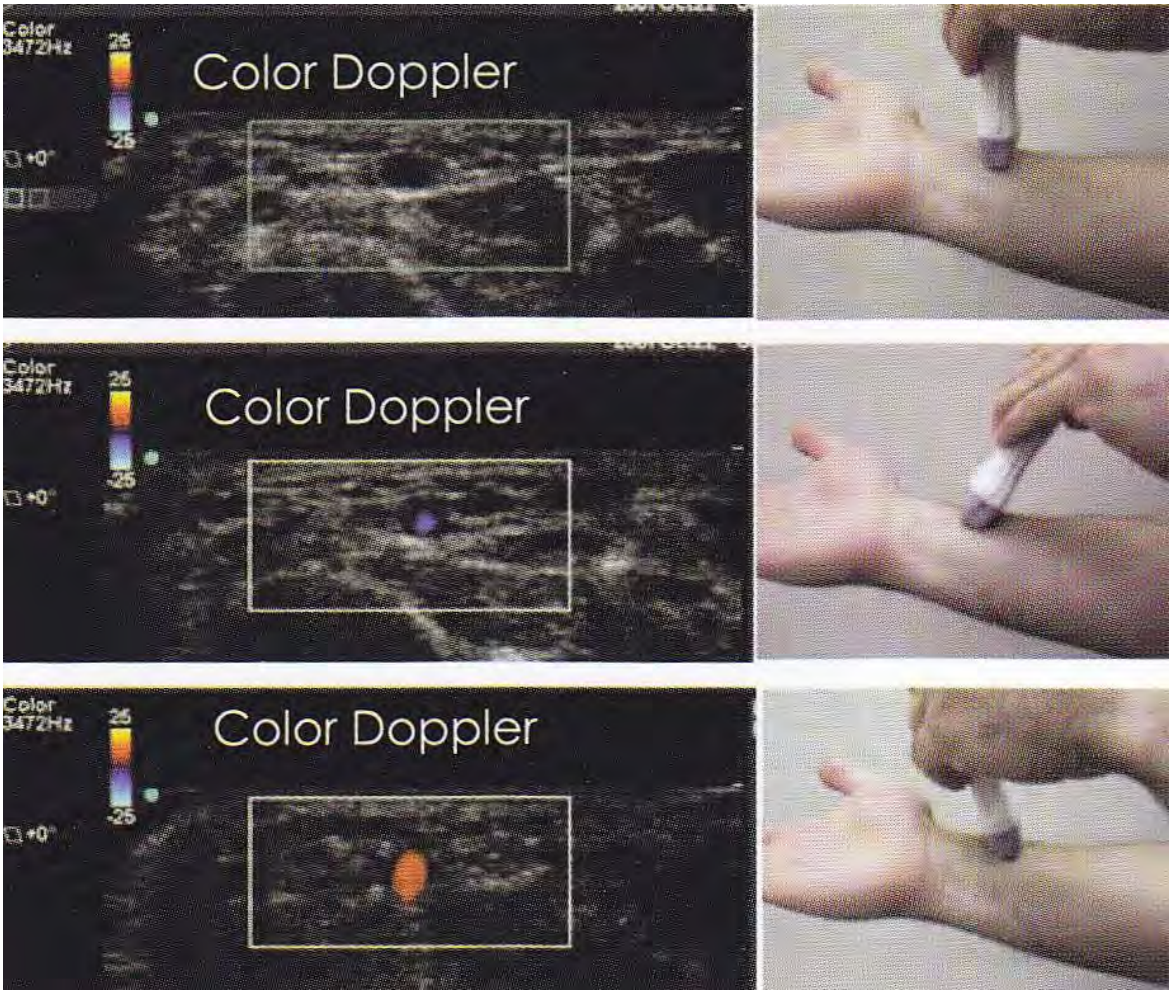
Beam steering to better 'see' the needle



The needle shaft is poorly visualised in figure A but becomes better visualised when beam steering is applied in figure B

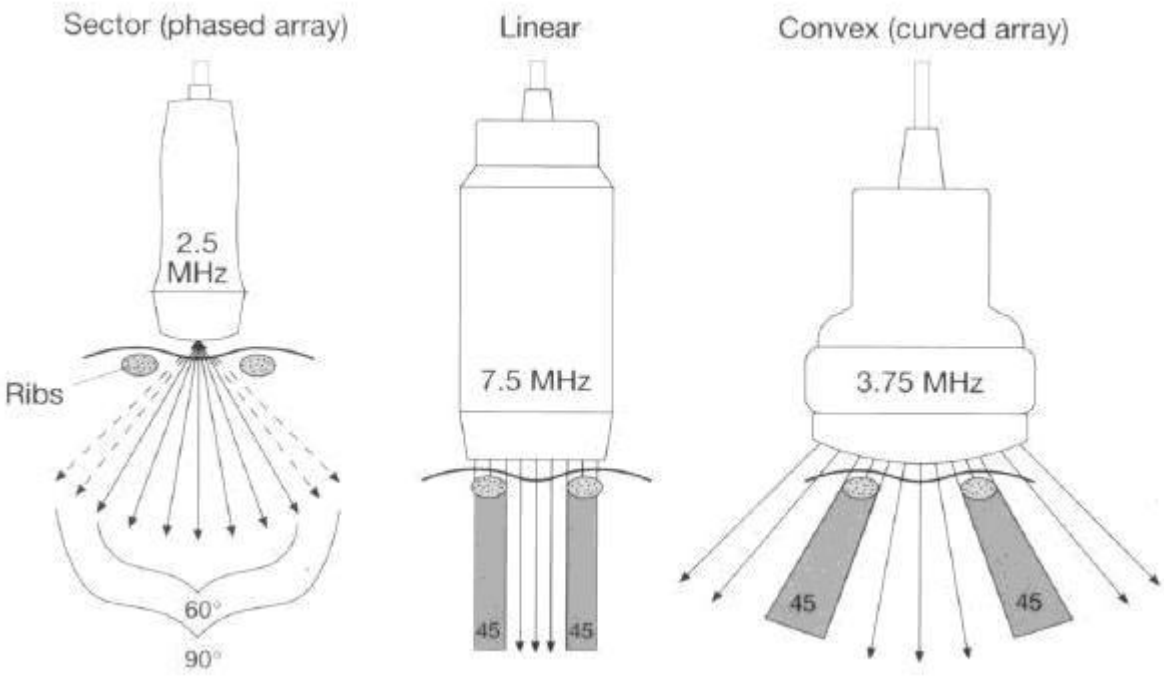
Colour Doppler

Many nerves have an associated vascular bundle. Colour Doppler is very useful for differentiating vascular structures from non vascular structures. In transverse imaging the directional behaviour of colour imaging is apparent. It is important to use a low flow setting to pick up both venous and arterial flow. A useful trick for venous flow is to compress the target with the probe for 1 – 2 seconds then release it. This often results in a surge of venous flow. One can also compress the limb distally and also get a surge of venous flow.



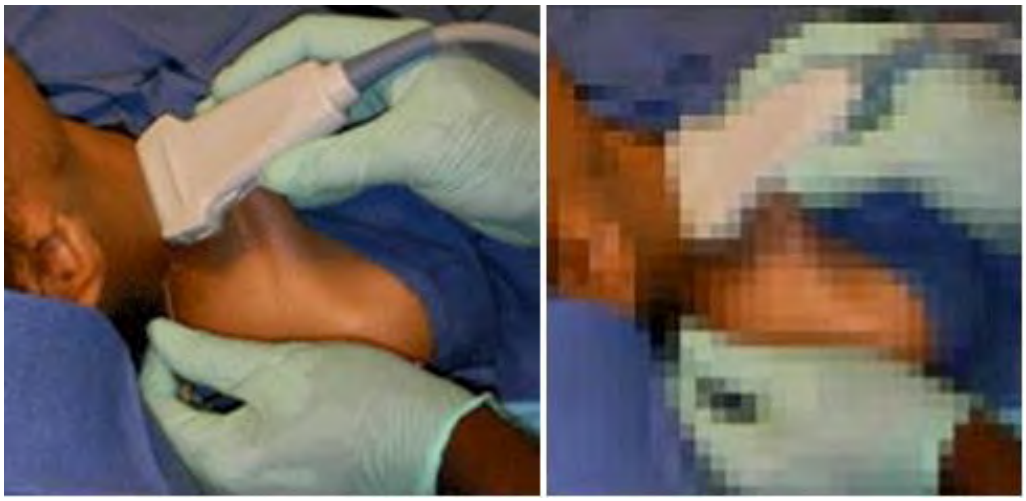
When the probe is at ninety degrees to the direction of flow no colour signal is present in the vessel. If it is angled slightly back or forwards colour flow becomes better demonstrated.

Transducers

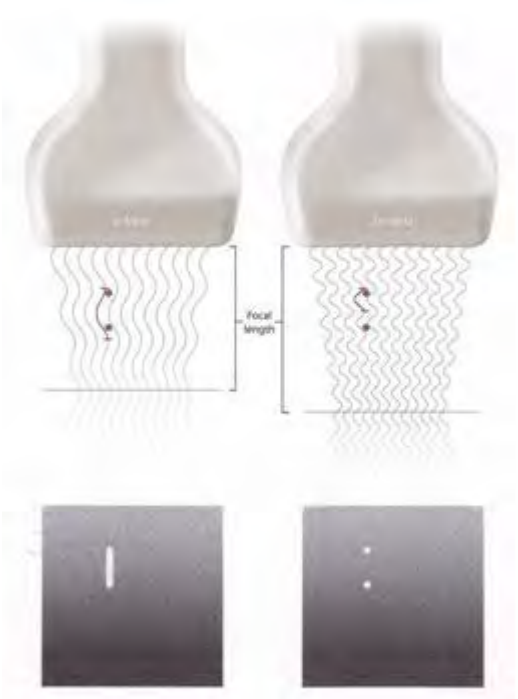


Pick the best transducer for each site. You should consider the size of the probe and how easy it is to handle, and its frequency and penetration. There is always a compromise between resolution and depth. For very superficial nerves you should pick the highest frequency probe to get the best resolution. For deep nerves however you need to select a probe that has better penetration at the expense of resolution.

High frequency (small waves) equals high resolution. You can use the analogy of small wave equals small pixels and large waves equals large pixels.

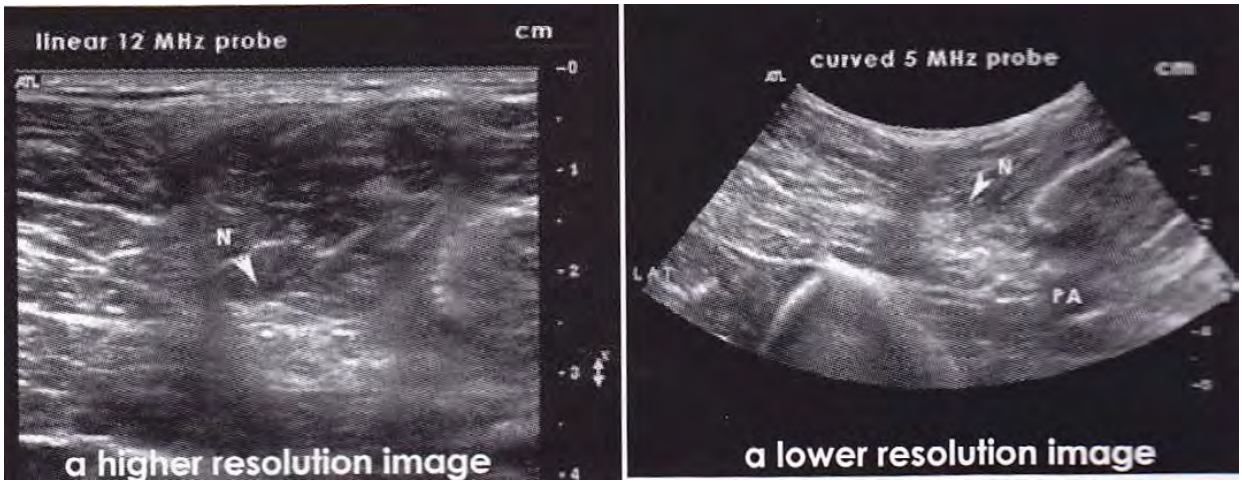


High Resolution ***Reduced resolution***



Schematic illustration of the effects of increasing transducer frequency to increase axial resolution

Schematic illustration of the effects of increasing transducer frequency and transducer diameter, to narrow the beam width and improve lateral resolution



The images show the difference between resolution and penetration with a high frequency linear probe and a lower frequency curved probe.

Probe Care

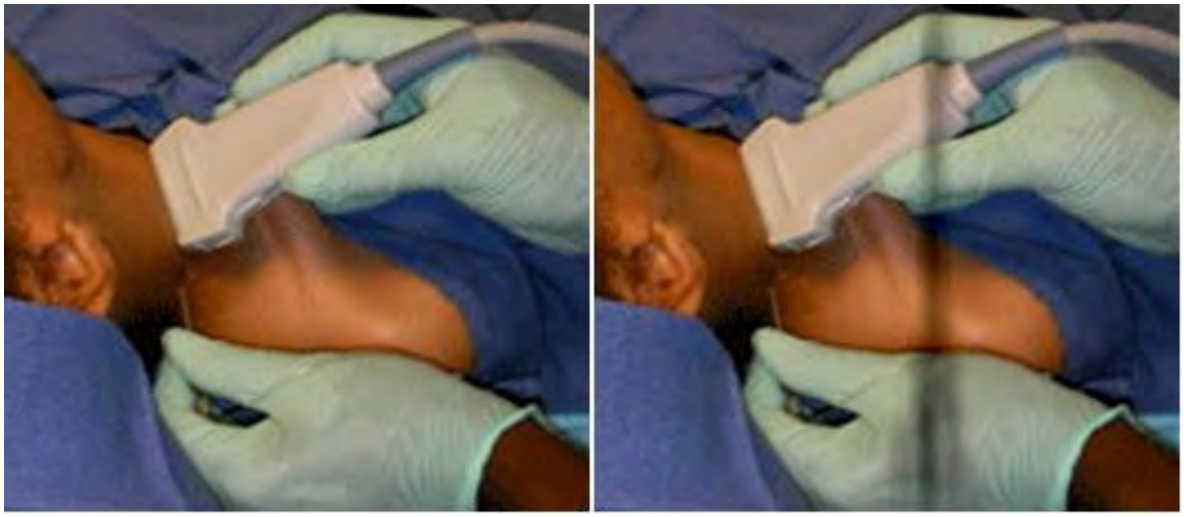
Probe care and maintenance is important to keeping the machine in good order.

Maintenance

- **Do**
  - switch off machine after use
  - 'freeze' when not scanning
  - handle transducers with care
  - clean transducers after use with soft towel or tissue paper
  - disinfect transducers after use

- **Don't**
  - drop, shock or knock transducers
  - disconnect or connect transducers when power is 'on'
    (Hot plug is OK on some new machines)
  - leave extension cord on the floor to be rolled over by the machine
  - leave extension cord in tension or in acute angles.
    The connecting points will be disrupted

Occasionally crystals in the probe head may fail giving the recognisable artefact of a dark line through the image.



Tips and Tricks

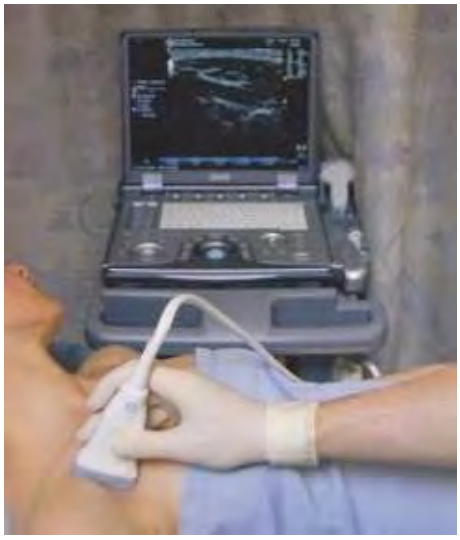
The probes cannot be autoclaved or they will be damaged. When working in a sterile field there are two solutions. You either wrap the probe in a protective covering, such as a sterile plastic sheath; or you paint the probe with iodine or alcohol. A sterile covering has the disadvantage that it usually degrades the image somewhat. Iodine has the advantage of staying moist for several minutes and also can be used instead of the ultrasound 'gel'. Alcohol dries quickly in the air and you often still need to use sterile gel.

If you are having a difficult procedure and the iodine dries out a simple trick is to squirt a few drops of your sterile local anaesthetic along the probe head, and you can keep imaging for several more minutes.

Handling the Probe

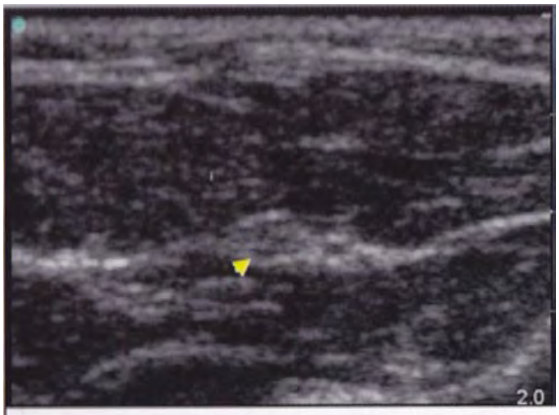
It is important to be in a position where the probe is steady. It can be a help to actually rest your wrist on the patient like when you are writing. The probe can then be slid, rotated or tilted to give the best image for you.

The 3 main ways of positioning the probe showing sliding, tilting and rotating.



The image shows good probe holding position with the wrist staple and hand steady.

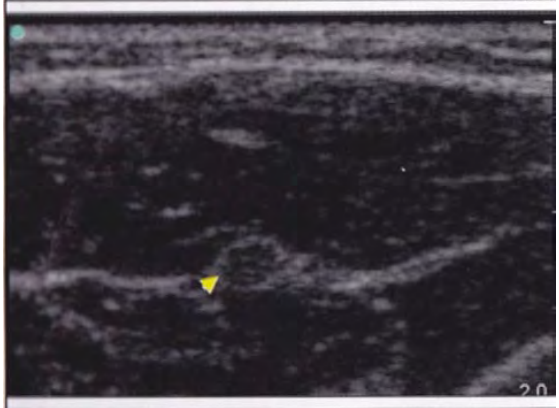
1. The impact of Transducer Angle on Nerve Imaging



Arrowhead = median nerve in the forearm

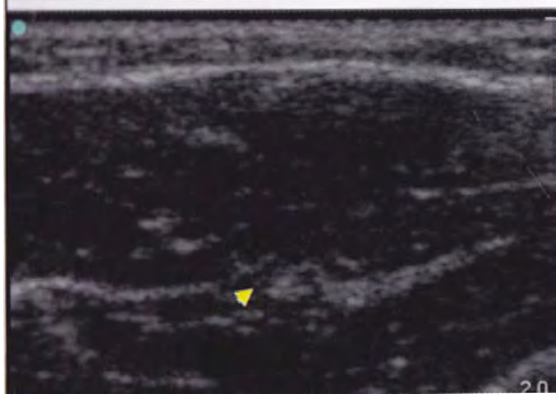
The transducer is scanning at a 90 degree angle.

The nerve (transverse view)



The transducer is scanning at a 75 degree angle.

The nerve is still visible but less clear.



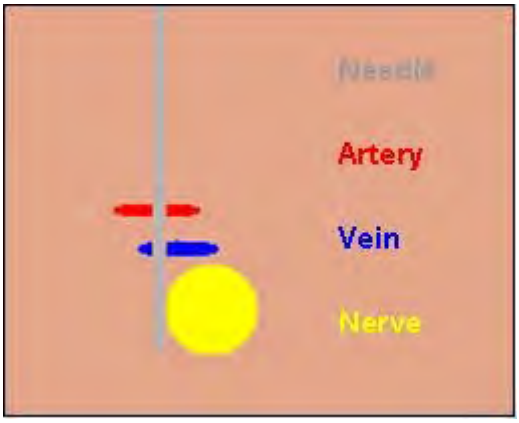
The transducer is scanning at a 45 degree angle.

The nerve is still visible but less clear.

Solution: angle the transducer slowly until the nerve

Tilting the probe excessively may degrade the image of a nerve. Nerves and tendons exhibit ‘anisotropism’ and will be less clear with an acute angle to the probe.

Many nerves are closely associated with a vascular bundle. Pressing too hard with the probe will occlude veins and even small arteries so you are not aware they are present. You may inadvertently puncture these vessels with the needle which will then bleed when you relax the probe pressure when you are finished.



Too much probe pressure may occlude the vessels so they are not seen, and they can be inadvertently punctured.

References

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Probe and needle techniques, artefacts and limitations of ultrasound

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The objective of placing a needle near to a nerve in order to deliver an appropriate dose of local anaesthetic agent requires an understanding of needle position relative to nerve. With ultrasound, this is by visualising the needle and target nerve at the same time. In principle this is easy, but in practice it is often more difficult than first imagined, and each part of the process is accompanied by potential problems which need to be understood in order to practice safely and effectively.

Physical assumptions are made in Ultrasound imaging that in certain situations lead to the production of artefacts:-

Echoes originate from the main beam
Echoes return after a single reflection
Ultrasound energy is uniformly attenuated
Ultrasound velocity is constant
Sound always travels in a straight path
The depth of an object is determined by time

Table 1. Physical assumptions in Ultrasound imaging

For 2D or B mode ultrasound, the US probe sends pulses of sound waves from piezoelectric crystal arrays. Returning echoes are received by the same crystals, each echo having an energy level which is displayed as brightness, and a depth under the probe calculated by the time delay from send to receive assuming a velocity in tissues of 1540 metres/sec. As sound passes through tissues the energy is attenuated. Attenuation is defined as the decrease in amplitude or intensity of a sound wave as it passes through a medium. The magnitude of this loss varies between tissues, and defined by the attenuation coefficient (α) according to the formula:-

Attenuation (dB) = α (dB) x 2 x depth of reflector(cm) x Frequency (MHz)

It therefore increases with higher frequencies and increasing depth.

Material	Attenuation coefficient (dB/cm)
Water	0.002
Soft tissue	0.3 – 0.8
Fat	0.5 – 1.8
Bone	13 - 26
Air	12

Table 2. Attenuation coefficients for tissues

The likelihood of reflection and echo creation is dependent on Acoustic impedance, which is the opposition of the tissue to the passage of sound waves, as defined by the product of tissue density (ρ) and acoustic velocity (v).

Acoustic impedance $\mathbf{Z = \rho V}$ $\mathbf{(kg^{-2}s^{-1})}$

Material	Density ($kg.m^3$)	Velocity ($m.sec^{-1}$)	Acoustic impedance ($kg^{-2}s^{-1}$)
Air	1.2	343	429
Water	1.1	1525	1.43
Fat	0.92	1450	1.33
Muscle	1.04	1580	1.64
Cortical Bone	1.9	4040	7.68

Table 3. Acoustic Characteristics of materials

As sound waves strike a surface between two tissues of differing acoustic impedance some of the sound is reflected. The greater the difference in acoustic impedance between two tissues, the greater the reflection at this barrier. Two principal types of reflector can be described, a specular reflector where the sound beam is reflected in a single direction and a scattering reflector where the energy is reflected in multiple directions. The former usually has a surface width of more than 1 wavelength while the latter has a surface width less than one wavelength.

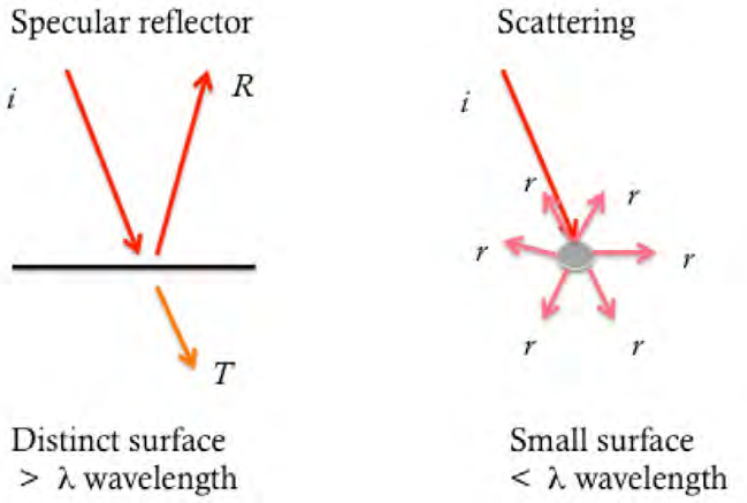


Figure 1. Specular and scattering reflectors. Incidence sound wave (i) with single reflection (R) from a specular reflector, and multiple reflections (r) from a scattering reflector. The acoustic impedance difference between tissues determines the relative amount of reflected to transmitted sound (T)

Imaging Artefacts [1]

An imaging artefact is described as any part of an image that does not represent the anatomical structures present in the area being examined. Ultrasound relies on physical principles to create that image and each part of the process of image production may be accompanied by errors. The US image is created by pulse formation, propagation, attenuation, reflection and echo detection, only some of which are user dependent. An understanding of the way in which ultrasound images are generated is important if one is become expert in its use. Artefacts are the result of a failure of Ultrasound to conform to the physical assumptions made in interpreting returning echoes.

Artefacts due to beam characteristics

The processing computer in the US machine believes that returned echoes are the result of only one beam of minimal width, and of defined shape. Unfortunately this is not true. The beam can be divided into three zones, the near field or Fresnel zone, a focus zone, and the far field or Fraunhofer zone. The near field depth is dependent on frequency (λ) and transducer radius (R).

Near field length = $R^2 / 4 \times \lambda$

Higher frequency transducers have a greater Fresnel zone depth. Beam divergence occurs in the far field and is controlled by a focusing lens in the probe or electronic focusing. Some machines have a user selectable focus and it is therefore important to set this at the target depth. Where there is no independent control of focus, the focus is automatically set for the depth at the centre of the screen. The main beam is assumed to be the only source of echoes, but crystals often possess multiple side lobes and grating lobes. A reflection from one of these will be placed as though it originated from the main beam. This is known as a **side lobe artifact**. These are usually weak echoes only seen within areas of low echogenicity such as blood vessels, bladder or cysts. As these lobes are of lower energy, changing the insonation angle or reducing gain will eliminate them.

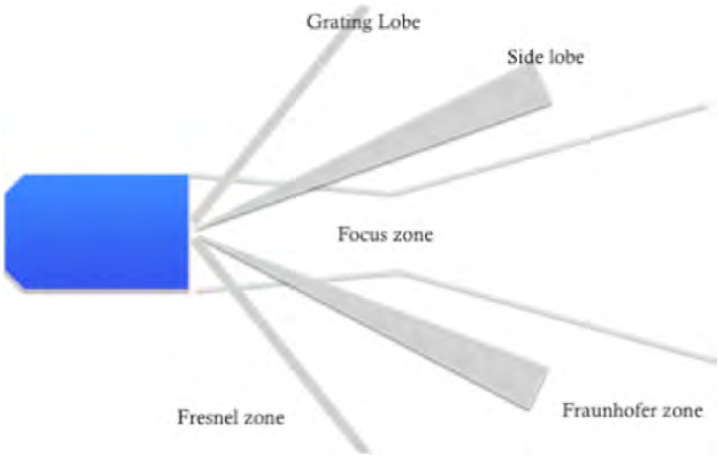


Figure 2. Schematic of beam characteristics. Multiple side lobes may be present. The machine assumes the beam is a single fixed pattern.

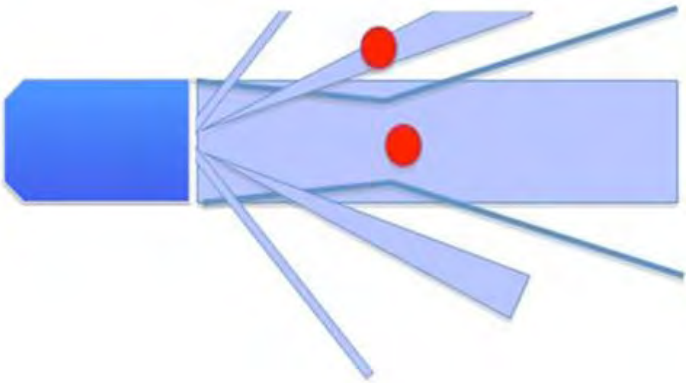


Figure 3. Side lobe artefact. Echo from a strong reflector in the side lobe is positioned as though it was within the main beam.

Beam divergence affects the lateral resolution of the system, so that two objects may be appear as one. The divergence angle is frequency dependent and given by the formula:

Divergence angle (degrees) = 70 λ/D where D is the diameter of the transducer.

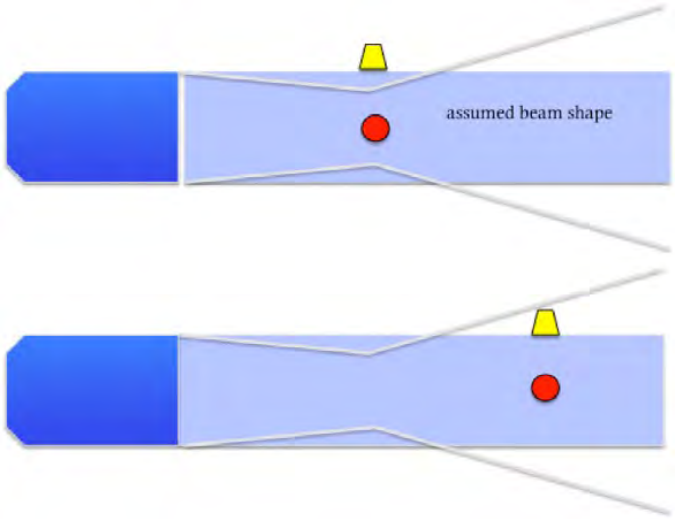


Figure 4. Beam width (lateral resolution) artifact. Grey area represents assumed beam. Note two reflectors the same width apart are combined as one in the far field, but only the red is seen at the focus zone.

Axial resolution is the ability to distinguish two points above and below each other in the US beam. It is a equal to half the spatial pulse length; Spatial pulse length is the product of the number of cycles in a pulse or ultrasound and the wavelength. Most pulses are of two or three cycles in length. Therefore the ability to distinguish two objects in depth is improved with increasing frequency.

Temporal resolution is of more concern in Echocardiography and is the ability to distinguish moving structures in time. Higher frame rates are possible with reduced depth and narrow frame width. See Ng and Swanevelder [2].

The discussion above makes it clear that what we see on the monitor is very dependent on a variety of tissue and sound properties, and explains why changing frequency changes the screen representation of tissue. Low resolution images will therefore suffer from loss of information – a form of drop out artifact.

Attenuation artefacts

The Transmission of sound through tissue is a function of acoustic impedance with air being notably poor at conducting sound energy. It is therefore important to eliminate air in the system. A **probe artefact** may occur due to inadequate coupling of the US probe to skin and is easily remedied with the use of acoustic gel or fluid. Acoustic gel should be sterile; 5% dextrose is a useful coupling agent particularly if nerve stimulation is used [3].

As sound passes through the through the tissues, energy losses occur due to heat (80%), reflection and refraction as previously described. As the sound energy falls during passage through tissues the amplitude of returning echoes becomes smaller. In order to compensate for this, the machine progressively increases the amplification of reflected energy in an attempt to normalise the grey scale on the monitor. This is known as **Time-Gain compensation** (TGC). On many portable machines this is automatic or there are controls for near, far and overall gain. More versatile machines have a series of sliders so the user can adjust each layer independently. Failure to adjust these correctly leads to artefacts due to over-gain or under-gain in the image. Inadequate gain (low energy signal) will result in a poor quality image with none or only very strong reflectors being visible. This is easily remedied by slowly increasing gain until a good image is revealed. As the sound energy levels are increased, excessive gain (high energy signal) results in increased “noise” from specular and

scattering reflectors resulting in a white out. Imaging in areas with high ambient light levels often results in over-gain problems, and mirror artefacts, which can be eliminated in lower light levels. *Always use the minimum amount of gain* to achieve the desired image. Whilst there are few defined health risks from Ultrasound [4], we should use as little power as is reasonable.

Figure 5. Banding of image due to inappropriate Time-Gain Compensation settings. There is over-gain in the second slice.

Post cystic enhancement or distal enhancement occurs when the sound passes through a material with low attenuation. As the sound reaches the next reflector its energy is greater than expected for tissue due to the TGC applied in post processing. This results in a stripe of increased echogenicity beyond the material. This usually but not always indicates fluid and is commonly seen deep to water containing structures such as cysts, bladder or blood vessels. In regional anaesthesia practice this may be misinterpreted as a nerve particularly deep to the axillary artery in infraclavicular block.

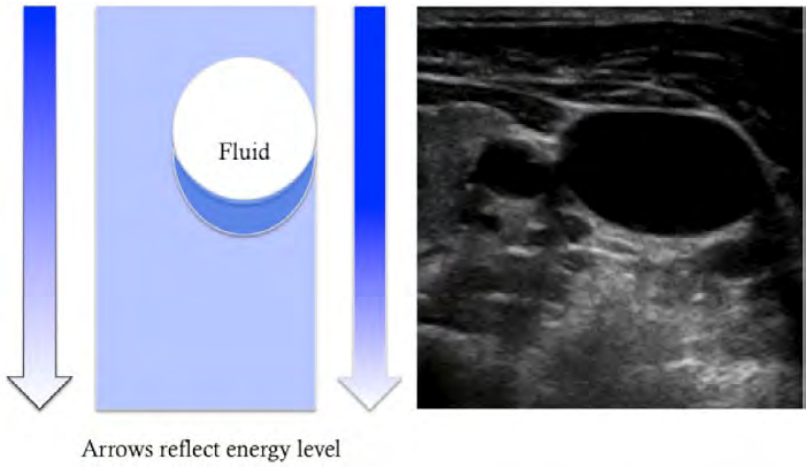


Figure 6. Distal enhancement. Note increased brightness deep to vessels.

Propagation artefacts

Acoustic Shadowing artefact occurs when the sound energy is reflected, rather than transmitted through tissue. This occurs with bone and air leading to dropout of information deep to the object. Probe repositioning may assist in viewing behind the reflector. It is used as an indicator of rib position in the supraclavicular fossa and assists in spinal imaging to determine the correct angle for needle placement [5].

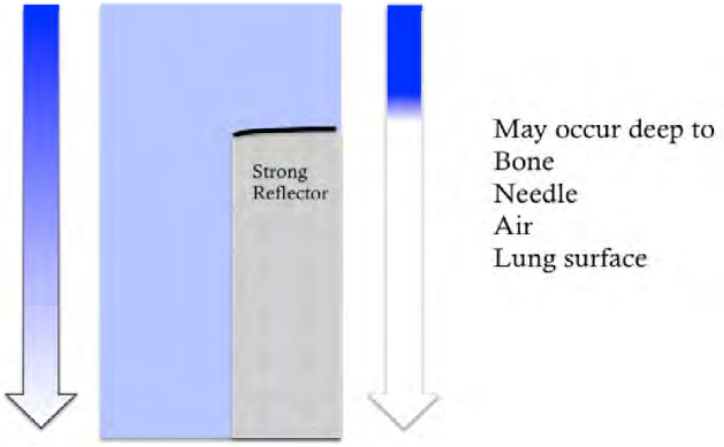


Figure 7. Acoustic shadowing. Strong reflector prevents Sound transmission deep to it creating a shadow

Reverberation artifact

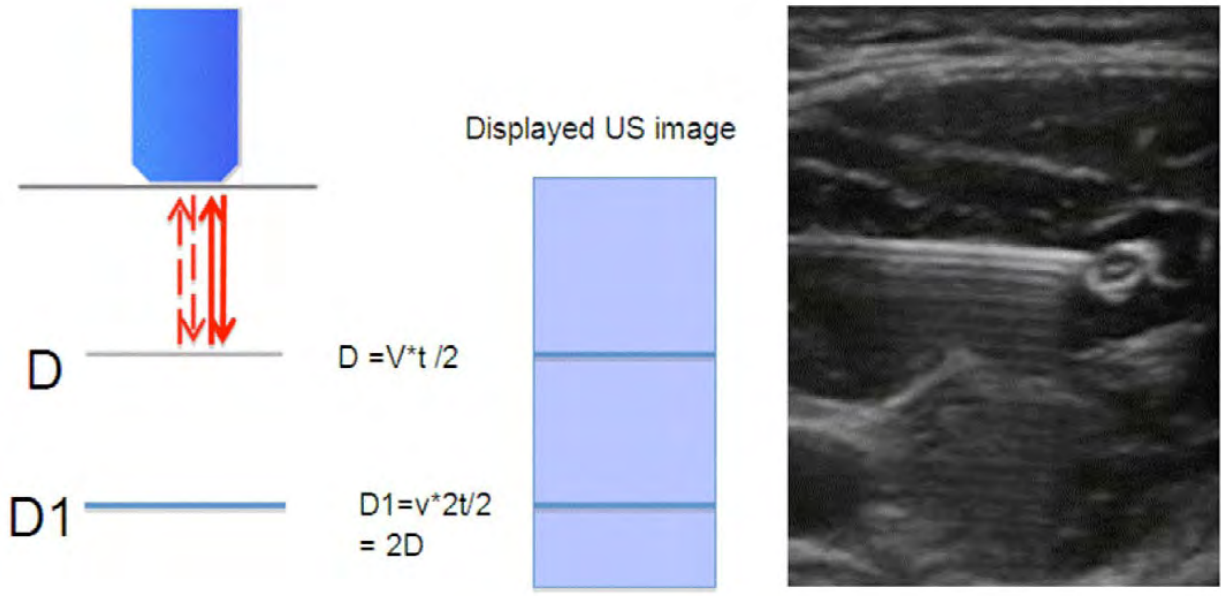


Figure 8. Reverberation. Reflection between two strong reflectors lead to multiple returning echoes at recurring time intervals which are placed in the image at a constant periodicity as a series of parallel lines. The US image to the right shows the reverberation artefact of a needle during block performance.

US assumes that an echo returns once to the transducer and the time interval denotes its depth. When there are two highly reflective surfaces the echo may travel back and forward between the two multiple times resulting in a series of parallel lines at fixed intervals. This may occur between probe and reflector or between two reflectors. Needles imaged perfectly in long axis produce a pronounced reverberation artefact which is useful in ensuring perfect needle positioning.

The comet tail artefact occurs when reverberation occurs between two closely spaced reflective surfaces. Reverberation between these produces a thin bright artefact which appears deep to the structures and gets progressively narrower with depth as the energy dissipates with each reflection. The close spacing means it is impossible to see each individual reflection. This artifact is a useful sign in lung imaging, its presence confirming pleural apposition ruling out a pneumothorax.

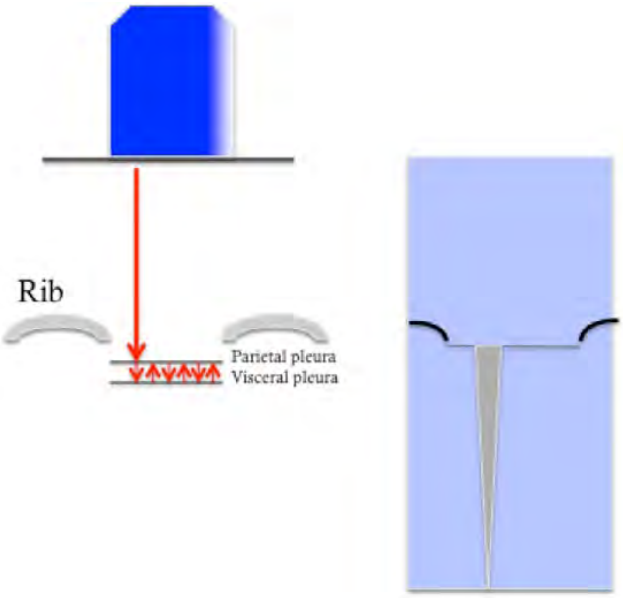


Figure 9. Comet tail artifact. Reverberation in a thin layer produces a bright reflection of narrow width.

Mirror artefacts occur when there is a strong reflector (e.g. Bone) deep to a weaker reflector (e.g. fascial layer). The image of the weak reflector is then displayed deep to the strong reflector due to the later timing of the returning echo. This is more likely to occur at higher gain settings and the artifact should disappear with probe angulation and reduced gain.

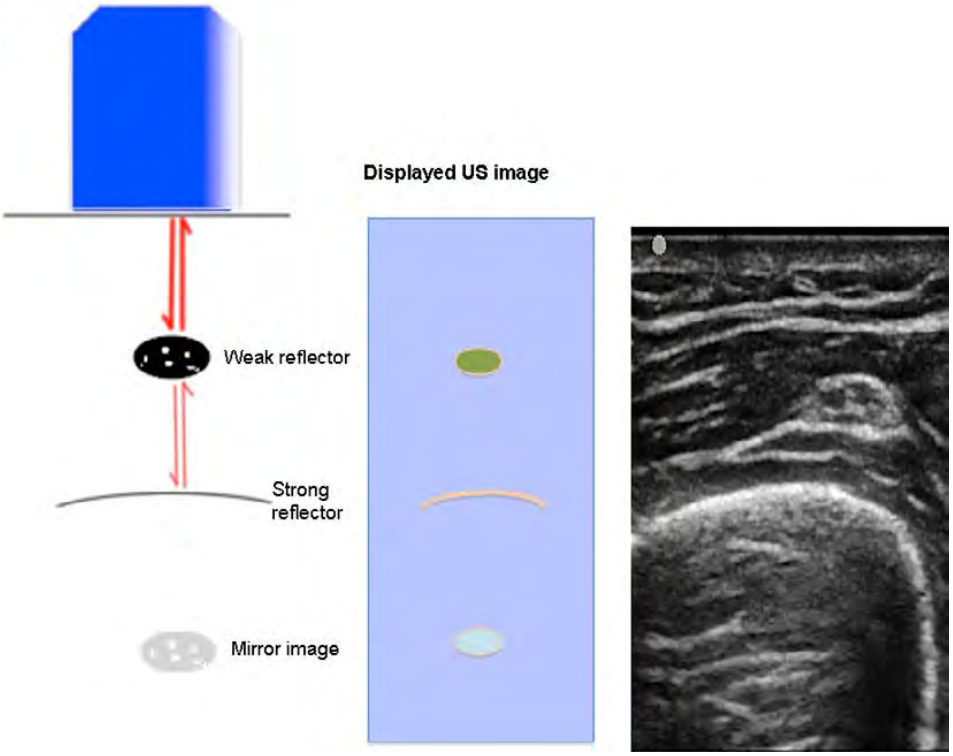


Figure 10. Mirror artefact. Reflected wave produces mirror image deep to strong reflector. US image on right shows fascial planes mirrored in humerus.

Anisotropy

Specular reflection obeys the laws of physics where the angle of reflection is equal to the angle of incidence. The strongest echo and therefore image occurs when the reflector is at 90 degrees to the sound waves. This property is very important in nerve imaging where the nerve can disappear from view with small deviations in angle. This directional dependence is termed Anisotropy and is well seen for many peripheral nerves. When searching for a nerve, you need to be aware of the path it takes and angle the probe to find the nerve. For example the popliteal sciatic nerve follows the line of the femur and anterior thigh so that the probe should

be held perpendicular to that direction. This means the probe appears to be pointing caudally as it rests in the popliteal fossa.

Velocity artefacts

The speed of sound transmission varies between tissues dependent on their density and elastic properties (see Table.1). The US machine places echoes dependent on a fixed velocity of 1540m.sec^{-1}. If sound is propagated at greater velocity it will appear in the image more superficial than it is, conversely a slower velocity will result in a deeper image. This is termed a **speed displacement artefact** but is probably of little significance in regional anaesthesia.

Where sound encounters two dissimilar tissues at an oblique angle to the beam then the transmitted beam is refracted towards the slower medium. The degree of refraction is given by Snell's Law:-

Sin θ *r* / sin θ *i* = c2 / c1

θ *r* = refraction angle; θ *i* = incident angle; c2 and C1 are the wave velocities in the two media

The refraction makes it possible for objects outside the assumed main beam to appear as though they are within the beam. Changing the beam angle will change the refraction angle and assists in recognition of this artefact.

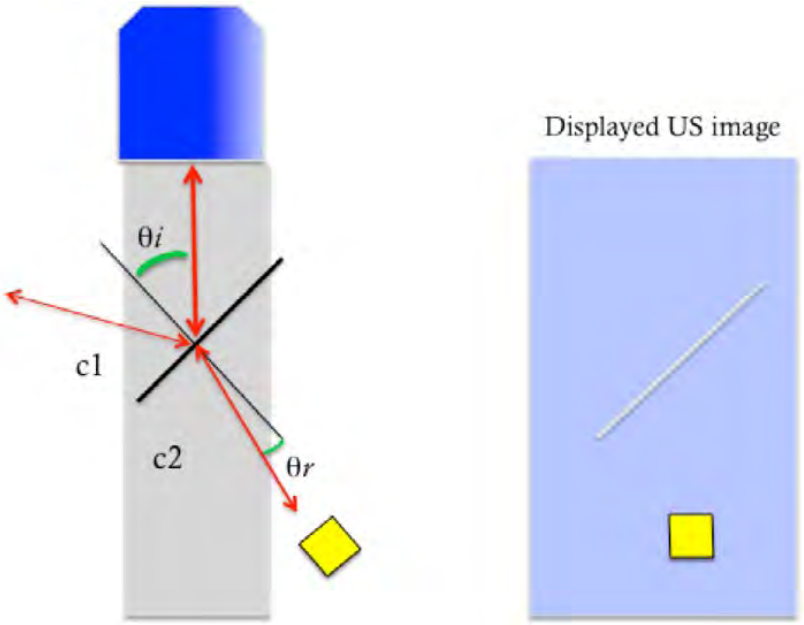


Figure 11.
Refraction artefact

This artefact is readily also seen as Edge shadowing distal to a curvilinear surface. A common example is the shadowing deep to the edges of blood vessels.

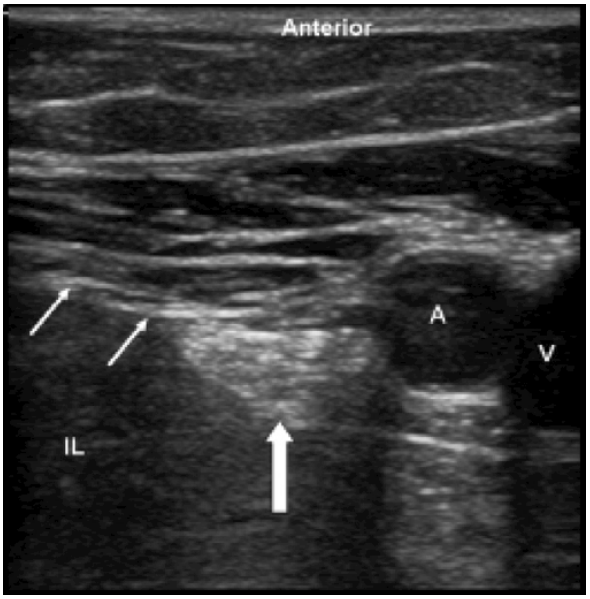


Figure 12. Edge artefact and distal enhancement around the femoral artery A. Bold arrow shows Femoral Nerve. Small arrows point to Fascia Iliaca.

Another speed related artifact described by Gray is the bayonet artifact [6] where there is an apparent bend in a needle placed through the Axillary artery.

Doppler artefacts

The Doppler effect is a change in frequency caused by relative movement between a sound source and sound receiver. If the two move together the frequency increases and if they move apart the frequency decreases. In regional anaesthesia practice, Colour Flow Doppler converts the frequency shift to velocity displayed on a colour scale. Interrogation of an area around the nerve is important to reduce the possibility of inadvertent vessel penetration and intravascular injection. This is particularly important in the axilla and supraclavicular regions.

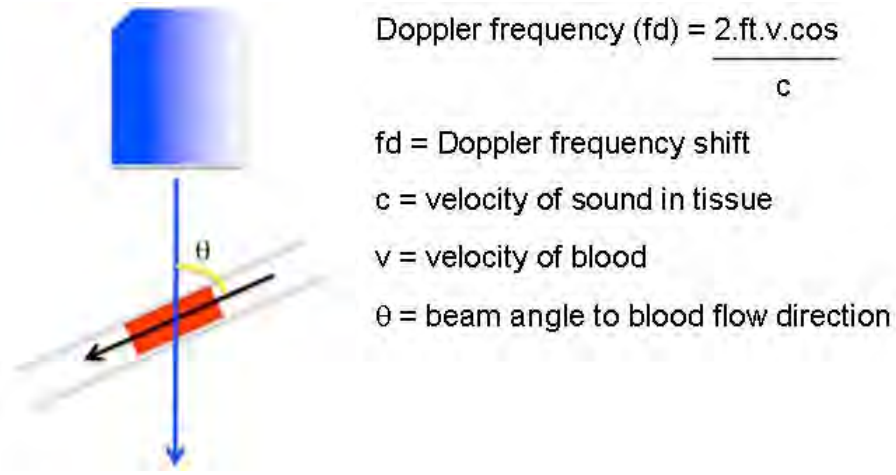


Figure 13. Doppler shift . Usual angle of insonation is 60 degrees

Interrogating the vessel at 90 degrees to flow (i.e. probe perpendicular to vessel) will not produce a frequency shift and therefore no colour flow indication since there is no movement of reflector (red cells) towards or away from the transducer. It is therefore vital that the probe is angulated in several directions to search for vessels in hypoechoic areas.

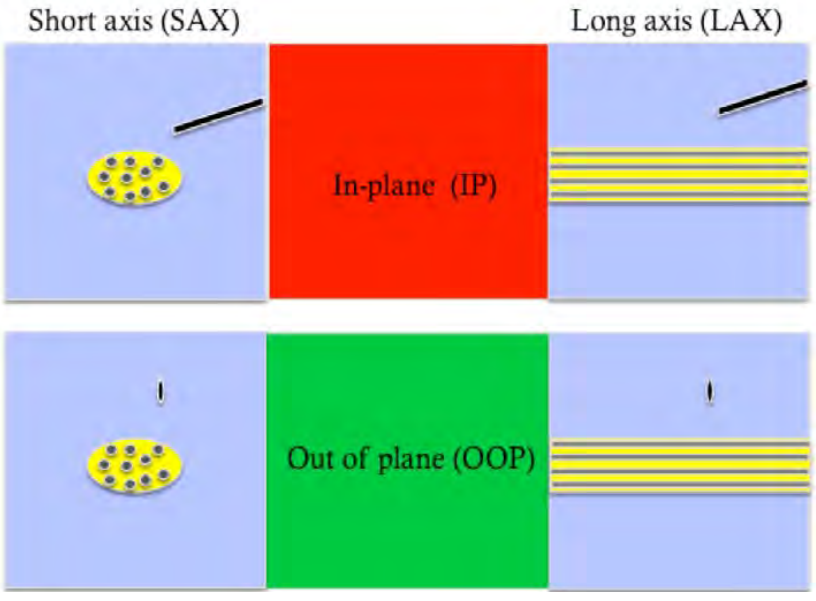
Needle Imaging with Ultrasound

AIR IS THE ENEMY OF ULTRASOUND – ALWAYS PREFILL NEEDLES AND CATHETERS

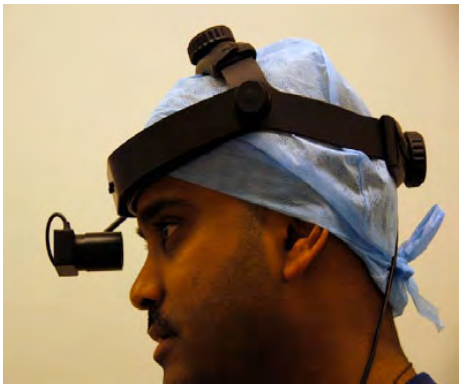
(A three-way tap on the syringe can be used to “lock” the syringe-tubing-needle system and prevent inadvertent entrainment of air prior to needle insertion).

Performance of a nerve block requires that we are able to image both the target and guide the needle to that target. There are thus four possible approaches to this. We can image the nerve either in its longitudinal or short axis, and we can image the approaching needle parallel to the plane of ultrasound (“in-plane”) or at right angles to the ultrasound plane (“out of plane”).

Figure 14. Four possible approaches of needle to nerve in an Ultrasound plane



Wherever possible our preference is for an in-plane SAX approach to the nerve. There are few reports of long axis nerve imaging for nerve blockade, and if both are visualised then the needle will be directed at the nerve rather than beside it. This may increase the risk of nerve injury. The disposition of local anaesthetic around the nerve may also be less well documented in long axis.



A further consideration concerns the ergonomics of block performance. Should the needle pass down your line of sight, or perpendicular to your line of sight? We have always performed blocks in the former way, which makes it easier for novices to find the needle by lining it along the probe by eyesight. Placing the monitor in your sight line directly behind your block site allows you to easily watch your hands and the monitor screen. Alternatively a head display can be useful in the operating room where the ambient lighting and space constraints make machine use more difficult.

Figure 15. Head mounted display

Out of plane needle imaging

The needle will cross the US beam at 90 degrees and you will see a small bright spot and a distal shadow (acoustic shadowing). The needle tip produces a reverberation artefact which is stronger than the needle shaft, but both may be difficult to visualise in tissues with significant echogenicity. It is important to realise the acoustic shadow indicates the direction of the ultrasound beam and does not confirm needle direction. OOP imaging is best performed with the needle at a steep angle so that is stays within the US beam. It is not clear why the needle is better visualised this way. Several methods may be used to aid needle imaging:

1. Translocation of the probe back and forth to follow the needle tip as the needle is advanced.
2. Jiggling of the needle may help locate the needle tip by observing tissue movement.
3. “Walk down technique”[7] where the needle is first passed at a shallow angle to find the tip, and then the needle is progressively angulated to approach the target.
4. Hydrolocalisation [8] in which small injections of fluid (0.5ml of 5% glucose if nerve stimulator is used) enable needle depth to be indicated by tissue distention with hypoechoic fluid deposition.
5. Nerve stimulation.

In plane needle imaging

The ability to see a needle in the imaging field is dependent upon the reflection pattern of the needle. Superficial targets enable the use of shallow needle angles with good needle imaging, and many of our blocks fall into this category (e.g. interscalene, supraclavicular, axillary, median, ulnar). Deeper targets demand steeper needle angles. Conventional needles passed at angles at 45 degrees or more become invisible and needle position is guided by tissue movement and hydrolocalisation. In these situations, a nerve stimulator may assist in finding the nerve and preventing intraneural injection (no twitch at < 0.2-0.5mA). At these steeper angles the Tuohy needle’s bent tip provides better imaging of the tip.

Strategies which may assist for deeper targets:

1. **Operator dependent**
   a. Heel and toeing of the probe
   b. Insert the needle some distance from the probe
   c. Hydrolocalisation
   d. Nerve stimulation

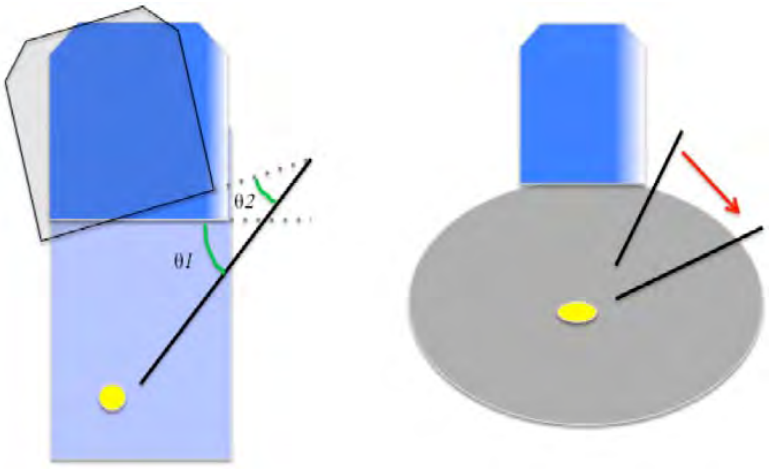


Figure 16. Probe heel and toe and entry away from probe

2. Machine selectable

a. Compound spatial imaging. Ultrasound is directed at multiple angles typically within 20 degrees of perpendicular to form a single composite image. This is able to reduce angle related artefacts and the graininess of images due to scattering and improve image quality.

b. Beam steering. In this modality, the US probe produces beams at several angles and superimposes the images on the screen. This functions like probe angulation in improving needle imaging by improving the angle between the needle and us beam. The angled beam does mean that the improved view is only available over a portion of the screen display which makes use for deep structures less easy. For these the probe is translocated as the needle moves towards the target.

c. Curvilinear probe – This may help with deeper blocks as the divergent beam strikes the needle shaft at a greater angle as it passes towards the target. As the needle approaches the target however the angle advantage reduces.

3. Needle types [9-13]

a. Standard needles. The bent tip of the Hustead or Tuohy needle has an increased reflection pattern and a recognisable shape.

b. Larger needle. These give better reflection patterns and due to increased stiffness allow for better control at depth and the ability to manipulate structures such as vessels.

c. Bevel position. The needle bevel should be orientated to face the probe so its shape is better discerned and reverberation around the tip is more likely aiding tip position visualisation

d. Echogenic needle. Improving the reflective properties of the needle by coatings or surface irregularities allows better imaging of needles at depth. Several needles have been brought to market in the last few years which vastly improve the visibility beyond 30 degrees.

4. Needle guide

a. Needle guides sound an attractive option in maintaining the needle in the ultrasound beam but they impose limitations on the freedom of movement which often makes them less useful.

5. Colour Doppler [14, 15]

a. Vibration induced in the needle tip may be visualised with Colour Doppler. The ColorMark device ™ has improved fine needle aspiration. Colour Doppler degrades the 2D image and reduces resolution of tissues which will be a potential problem for regional practice.

b. A piezoelectric vibrating needle has been described but no commercial products are available.

c. Ultrasound transducer in a stylet [16].

Suggested approach to a block

- Assess patient for suitability: neurological / infection or allergic problems which may affect your choice.
- Decide on appropriate block for surgery and discuss options with the patient to reassure patient and gain consent.
- Use compound imaging. + Echogenic needle for deeper targets.
- Consider beam steering
- Assemble the required equipment for your block.
- Select the appropriate local anaesthetic agents.
- Ensure full monitoring and IV prior to block commencement.
- Position patient for the block.
- Perform a 2D pre-scan of the area to find target nerve or plexus.
- Optimise nerve imaging (frequency, depth, gain, focus).
- Colour Doppler to check for vascular structures.
- Plan needle entry and route to nerve.
- Prepare a sterile field and place probe in suitable cover with gel.
- Locate ideal nerve view and probe angulation.
- Guide needle under skin at a shallow angle and find needle if necessary by translocation of the probe.
- Realign needle towards target and advance SLOWLY maintaining a view of the needle tip. STOP if the view of the tip disappears and move probe to find needle. Realign and continue advancing.
- Aim needle to just miss the nerve or enter the fascial plane containing the nerve.
- Confirm appropriate needle position with small injection(s) of 0.5ml fluid
- Once needle in place slowly inject small volumes of local anaesthetic and aim to surround nerve. If filling is eccentric reposition the needle. STOP if there is no hypoechoic area of local and assume vascular placement. Check patient regularly (I do not sedate patients for blocks)
- Terminate injection when the nerve(s) are bathed in local anaesthetic.

STOP INJECTION IMMEDIATELY IF

- Patient complains of pain, perioral numbness, fainting, collapse.
- There is resistance to injection. High injection pressure may be intrafascicular resulting in Nerve injury.
- No hypoechoic local anaesthetic or tissue distension can be seen - assume either you are not visualising the needle tip (reposition probe) OR you are intravascular (reposition needle).
- Nerve swelling occurs – assume intraneural injection - reposition needle.

Local anaesthetic toxicity – Be prepared and have a plan.

A recent paper suggests [17] there is poor compliance with resuscitation guidelines for LA toxicity. Make sure you have these available at every site where local anaesthesia is delivered to ensure the best management in the event a collapse.

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Overview of ultrasound guided regional anaesthesia of the trunk

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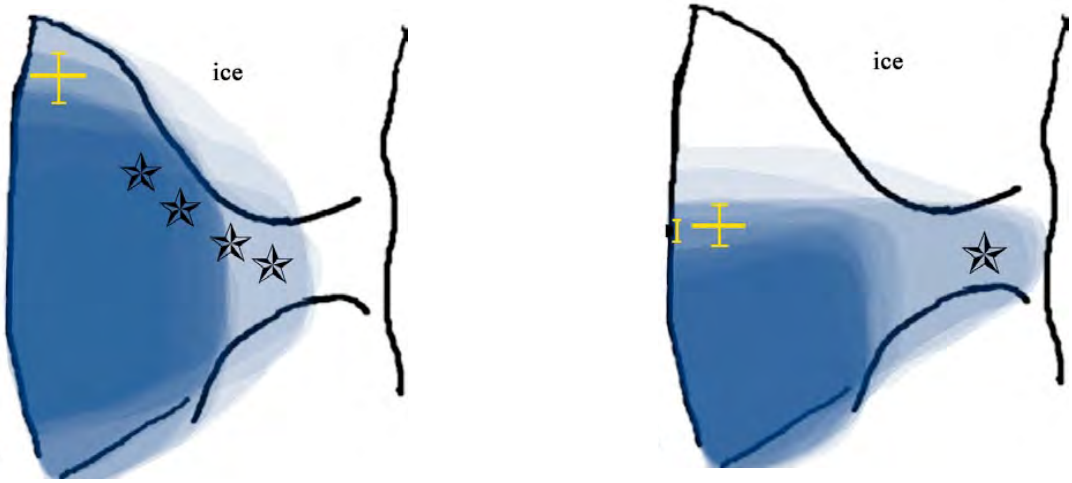
The application of ultrasound in regional anaesthesia has created renewed interest in peripheral nerve blocks for surgery on the thorax and abdomen. This has coincided with a decline in epidural use over the last decade. This trend has resulted from a lack of proven mortality benefit (MASTER trial), a move toward fast track surgery and early mobilisation, reduced access to high dependency beds and specialised care, and growing concerns about the risk of neuraxial complications both in the medical and lay community. Rather than identifying specific nerves, ultrasound can be used to clearly identify fascial planes, bony landmarks and patterns of local anaesthetic spread to provide effective analgesia while minimising potential complications like vascular puncture or damage to underlying viscera.

Ultrasound for spinal imaging prior to neuraxial blockade has also provided greater insights, particularly in challenging patients – for example the morbidly obese or scoliosis. Real time needle guidance for neuraxial blocks has been practiced by only an experienced few, but the basic imaging is easy to learn. This is not covered here.

Transversus Abdominis Plane & Ilioinguinal Block

TAP blocks have gained widespread use in Australia with the availability of ultrasound. They are useful to provide analgesia for the incisions of abdominal surgery. Local analgesia specific to the incision appears to provide good conditions for mobilising postoperative patients without motor block or hypotension. As the visceral component of postoperative pain is not reliably covered, they should be used as part of a multimodal analgesia regimen including an opioid.

The main approaches to this neurovascular plane of the abdomen are posterior and oblique subcostal. Posterior TAPs are useful for incisions below the umbilicus, usually performed as bilateral single-shot injections. The oblique subcostal approach is often associated with bilateral catheter insertion for ongoing analgesia with supra-umbilical or full length midline incisions.



Superimposed block distributions to ice from multiple posterior and subcostal TAP blocks. Mean block height and 95% CI displayed. (P.Hebbard)

Anatomy

The transversus abdominis is the innermost muscle layer of the abdominal wall. The TAP plane is located immediately superficial to this muscle and its aponeurosis. The internal and external oblique muscles and aponeuroses are located superficial to the TAP plane. It is worth noting the surface anatomy of these muscles and their aponeurotic continuations, predicting what is visualised on the US screen. In particular note the lip of transversus abdominis muscle following below the costal margin and extending deep to the rectus muscle; this is the key to the subcostal approach. The oblique aponeuroses join to form the linea semilunaris, which attaches to the rectus sheath. The best appreciation of this anatomy is gained by scanning whole abdomens, as it is a consistent pattern.

The TAP is the neurovascular plane of the abdomen, continuous with the thoracic paravertebral space. It contains loose fascia, blood vessels, and the multiple branches of the anterior rami of the spinal segmental nerves from T7 to L1. Nerve plexuses are concentrated around the main vessels, the deep circumflex iliac artery and the superior and inferior epigastric arteries.

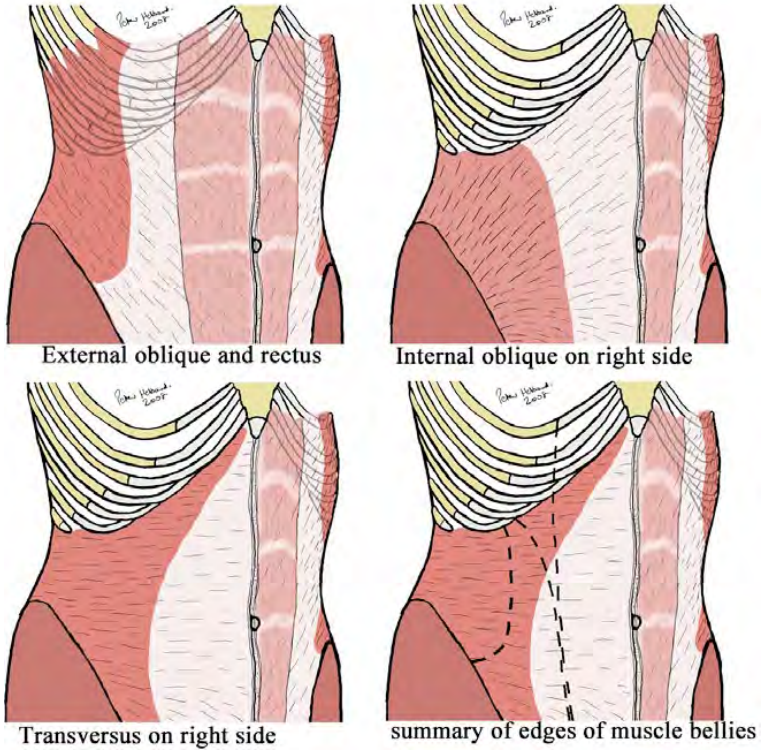
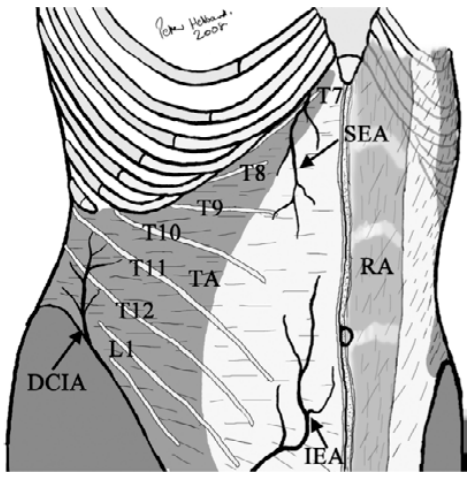


Diagram of TAP superficial to TA (transversus abdominins) - RA (rectus abdominis), SEA (superior epigastric artery), IEA (inferior epigastric artey), DCIA (deep circumflex iliac artery)



Near the mid-axillary line the nerves give off a lateral branch which penetrates the overlying muscle to supply the skin of the lateral abdominal wall. The anterior branches continue forward to pierce the lateral rectus sheath to supply this muscle and the skin overlying it. Blocks performed anterior to the

mid-axillary line would only be expected to anaesthetise the anterior branches, TAP blocks to encompass the flank region need to be performed more posteriorly.

The nerve runs a variable length deep to the rectus sheath before piercing it; the nerves T7-9 may run only a short course in the TAP – thus the oblique subcostal approach should be performed close to the costal margin and begin deep to the lateral part of the posterior rectus sheath.

It is worth noting the course of the ilioinguinal nerve in the TAP plane is variable. Branches of L1, the ilioinguinal and iliohypogastric nerves, may remain deep to the transversus abdominis and iliac crest and enter the TAP plane after the mid axillary line.

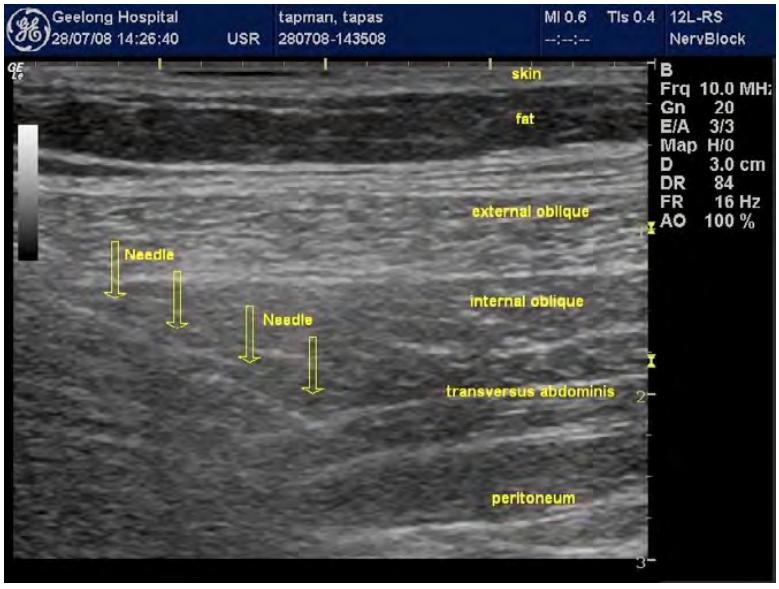
TAP blocks intended to include the ilioinguinal nerve should be performed anterior to this line. Beyond the ASIS, these nerves may pierce the internal oblique and run between the oblique muscles. The nerves can often be identified in the plane with an accompanying blood vessel, so colour flow helps. TAP/ilioinguinal blocks for hernia repair and Pfannensteil incisions may be best placed just cephalad to the ASIS.

Posterior TAP block

These are usually performed as a single shot blocks for lower abdominal surgery. Unilateral blocks can be used for inguinal hernia repair and appendicectomy, with midline and Pfannensteil incisions requiring bilateral injections, correctly placed posterior TAPs should provide analgesia from the umbilicus to symphysis pubis. While catheters can be used, studies have demonstrated a duration of action from a single injection beyond 24h [1].

While originally described as a ‘double-pop’ technique without the use of ultrasound [2], the availability of quality ultrasound systems has greatly increased their popularity in Australia. Ultrasound has been shown to improve the accuracy of injection and may reduce the risk of visceral injury [3,4]. There is some debate about which approach is more efficacious. There is some evidence from MRI studies that TAP injectate spreads to the paravertebral space; McDonnell postulates that this explains why TAPs performed more anteriorly may be less efficacious [5]. On the other hand, if the inguinal area needs to be covered, placement closer at the anterior axillary line will perhaps more reliably account for the course of the ilioinguinal nerve.

Most anaesthetists get plenty of opportunity to perform these in anaesthetised patients, distant to major vascular/neural structures and viscera – making them an ideal beginner’s block. Time to practice the in-plane technique! Once the learning curve is conquered it should only take a couple of minutes each side.



Ergonomics are important. I stand on one side of the patient with the US machine on the opposite side. While both sides can be blocked from the one approach, it is less ergonomic so while learning, swap sides – it will probably be faster.

I use a high frequency 50mm linear probe set at 8-10MHz. Utilising harmonics/ THI (tissue harmonic imaging) often makes the fascial

planes more apparent. Angling the probe and using variable probe pressure will also help identify the anatomy. I use a 100–120mm short bevel needle. Sonographic needles such as the Pajunk sonoplex often help as the tip needs to be seen at a depth of >3cm. To help with needle visibility, insert the needle at least 2-3cm away from the probe, allowing a flatter trajectory. 'Heeling' the probe or using a beam steer function, so the US waves are more perpendicular to the needle, is another useful trick.

Aim to fill the plane between the deeper two muscle layers from the costal margin to the iliac crest around the mid axillary line, distending it with at least 20mls of local anaesthetic solution, ropivacaine 0.375 or 0.5% depending on what I consider a safe dose for my patient.

When imaging this area, a few simple rules will help you find the correct plane –

1. Transversus abdominis is the deepest muscle layer. It is thinner and appears darker than the obliques. Occasionally a fat layer may separate the TA from the peritoneum and should be distinguished from muscle.
2. If uncertain, image more anteriorly to identify the linea semilunaris at the edge of the rectus muscle below the umbilicus. As you scan laterally from here you will note the three muscle layers arising from this structure.
3. Subcutaneous fat compressed beneath the probe may appear as another muscle layer. The above manoeuvre and varying the pressure applied to the probe will help you to identify this.
4. If using a short bevel needle, you should appreciate a subtle pop as you traverse from external into internal oblique muscle. There is another subtle pop as you leave internal oblique and enter the TAP plane. Because the fascia is dragged by the blunt needle tip, you may need to advance the needle further beyond the level of the plane to feel it. On occasion you will not feel a pop but observe tissue recoil on the screen.
5. Pay careful attention to the pattern of spread of the initial injection. If in the TAP plane you will observe spread of injectate along the plane in a lentiform shape. Injecting into muscle causes a more diffuse swelling and highlights muscle fibers. This is usually internal oblique – advance the needle under vision, look and feel for the pop, and try again. If in TA, withdraw slightly while injecting and observe for the change in pattern of spread. While learning it may help to inject saline initially and change to local anaesthetic when the desired spread is observed.

Oblique Subcostal TAP catheter insertion

This technique is better suited to midline incisions that extend above the umbilicus or upper midline incisions compared to posterior TAP block. Compared to epidural, lower limb motor block, hypotension, urinary catheterisation, and concerns about neuraxial complications and anticoagulation are avoided - gaining approval with ward nurses and surgeons as well as anaesthetists. In addition, this is a useful technique when a planned laparoscopic procedure has evolved into a midline incision, as the catheters can be safely inserted under anaesthesia. Unilateral subcostal incisions, such as open cholecystectomy, are better suited to paravertebral analgesia.

To date there is one prospective study comparing epidural infusion to subcostal catheter boluses for upper abdominal incisions, demonstrating no difference in pain scores [6], and at least 2 randomised placebo-controlled trials currently underway examining their efficacy for midline abdominal incisions [7].

This is a more advanced technique than posterior TAP block, and can provide a large area of coverage. *Hydro-dissection*- distending the plane with injectate, advancing the needle to the leading edge, and injecting again to open up the plane, allows broader coverage and creates a space for catheter insertion and subsequent injections. It requires a degree of dexterity with probe and needle. I usually insert a catheter, aiming to extend the block for 3-5 days, requiring proper sterile technique.

I usually perform this injection in anaesthetised patients at the end of surgery. It is preferable that the patient be mechanically ventilated, as spontaneous ventilation movements tend to make the procedure more difficult. I request the surgical drapes be left on (if not contaminated) and the surgical dressing not applied (this avoids inserting the catheter through the dressing – with predictable results should the dressing be later changed!). Stoma bags can be a nuisance; depending on their position (gentle skin traction by an assistant may help).

Remember to stay close to the costal margin, this is where you will find transversus below the rectus sheath. The upper nerves only have a short course in the plane in this region before penetrating the rectus sheath. Use colour flow before you begin to identify the superior epigastric artery.

I use a long (11cm) 18G Tuohy needle. Ideally, a 15-20cm needle would provide longer hydro-dissection and potentially better coverage. It is helpful to impart a ~20 degree angulation in the distal third of the needle to control the tip on advancement, as it can be difficult to direct the needle anteriorly in the plane once the needle has traversed the abdominal wall.

I introduce the needle from medial to lateral through rectus muscle, close to the costal margin and xiphisternum where transversus can be seen. Upon reaching the posterior rectus sheath, I usually inject a few mls of local anaesthetic solution (thus combining a lateral rectus sheath block to hopefully catch the uppermost nerves) before advancing through it. Once a pop is felt, or the layer recoils on the sonogram, begin injecting again. Spread along the TAP should be seen (if transversus swelling occurs, withdraw the needle while injecting to observe for the characteristic spread), then begin hydro-dissection along the costal margin. Take care not to enter the plane between the oblique muscles. To extend the block to the lower abdomen, advance along the costal margin and towards the anterior superior iliac spine. Sometimes needle withdrawal and re-siting into the plane more distally can help.

Sterile setup for subcostal catheter insertion. Note insertion point and assistant to provide injection.

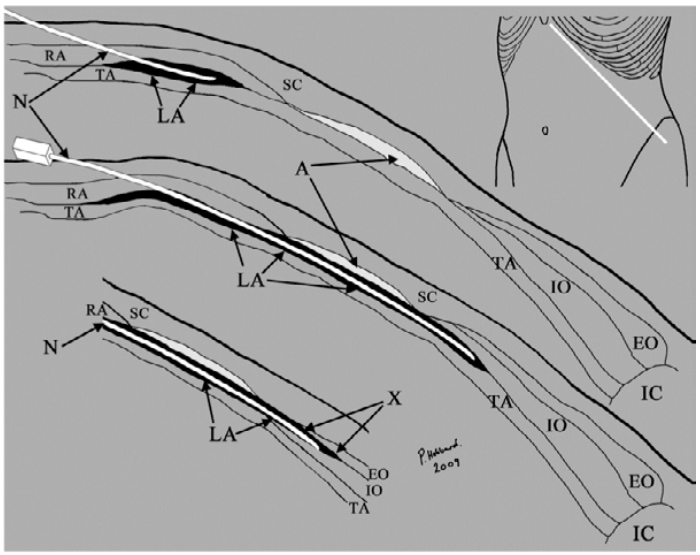
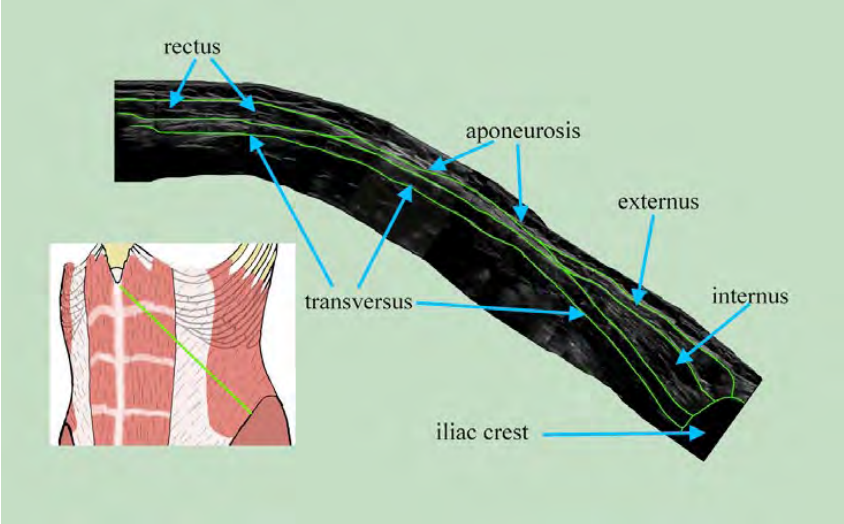


Diagram of correct plane for subcostal oblique block. Top right diagram shows direction of needle on abdomen. Lower diagram shows incorrect spread between oblique muscles. Note curve on needle - initially faces up then down. RA (rectus abdominis) TA (transversus abdominis) A (aponeurosis/linea semilunaris) IO(internal oblique) EO (external oblique) IC (iliac crest) LA (local anaesthetic)

X=incorrect spread



TAP catheters should be utilised as part of a multimodal analgesic regimen. Patients need an oral or PCA opioid and adjuvants to provide visceral analgesia in the early postoperative period. After the first postoperative day, somatic analgesia becomes more relevant to aid mobilisation and the opioid-sparing effect becomes apparent.

Local anaesthetic delivery via bilateral TAP catheters deserves some consideration. The two options are continuous infusion or intermittent bolus. There are advantages and potential problems with each. To date there is no comparative data as to which delivery technique is optimal.

Intermittent bolus has the advantage of providing the patient with minimal attachments, reducing the risk of dislodgement and improving mobility. Spread through the plane is likely more extensive when it is distended by a bolus, potentially offering more complete coverage. The main disadvantage of this approach is the potential for inadvertent intravenous injection and systemic toxicity. While education and hospital protocols help reduce the risk, this concern can be addressed by using unique local anesthetic delivery connectors (such as the Correct Inject from Portex, Smith Medical), recently arrived on the market, with matching pre-filled syringes supplied from pharmacy. Resistance to injection of 20ml down an 18G epidural catheter has been overcome using the Springfusor device (Go Medical).

At Geelong Hospital ward nurses have delivered intermittent bolus for more than 250 patients with TAP catheters, after completing an education package. Patients receive 20mls 0.2% ropivacaine to each catheter, 6 hourly (i.e. 320mg ropivacaine over a 24h period). Most patients report reduced pain, especially with movement, following a bolus. A few selected patients have received 4 hourly injections to improve their analgesia.

Continuous infusion via electronic or balloon infusor devices have been adopted by some other institutions. While the safety concern of inadvertent intravenous bolus is addressed, most have used two local anaesthesia pumps to deliver the infusions (0.2% ropivacaine @ 5-7ml/h each side). This has cost implications as well as increased risk of dislodgement and nursing complexity.

Thoracic Paravertebral Blockade

Paravertebral block involves the use of local anaesthetic lateral to the vertebral column to produce ipsilateral anaesthesia and analgesia by blockade of the thoracic segmental nerves. The key advantages over intercostal blocks are broader coverage (can cover multiple dermatomes and include blockade of the posterior primary ramus) and the ability to insert a catheter – avoiding multiple needle insertions. In the lumbar region it constitutes a psoas compartment block.

Single level injection with catheter insertion constitutes my usual approach for analgesia as part of a multimodal regimen for unilateral incisions in thoracic dermatomes, such as thoracotomy and nephrectomy. I have found it particularly useful for management of analgesia for fractured ribs in difficult cases. A bolus dose of 15-20ml can cover 5-9 thoracic dermatomes. Single shot blocks performed at multiple spinal levels has been described as an anaesthetic technique for breast surgery. There are case reports and prospective studies of bilateral paravertebral blocks being used for obstetric analgesia, and even as an alternative to general anaesthesia for abdominal surgery.

Problems associated with epidural blockade, such as lower limb motor blockade, urinary retention, hypotension, and concerns about neuraxial nerve damage related to haematoma or abscess formation may explain the resurgence in its use. Recent reports suggest improved long term outcomes, with reduced chronic pain and cancer recurrence after breast surgery, which is now the subject of prospective study.

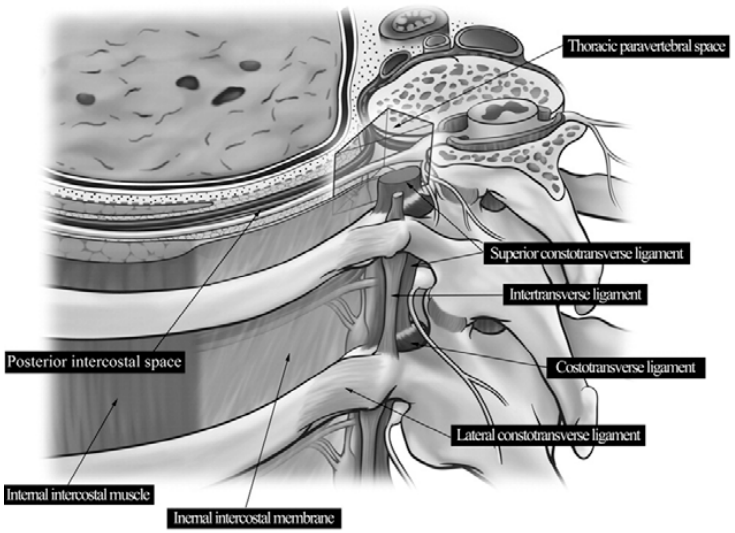
The blocks may be safely performed in the anaesthetised patient, improving patient acceptability and allowing flexibility with postoperative analgesic plans, for example when a laparoscopic cholecystectomy turns into an open procedure.

Anatomy

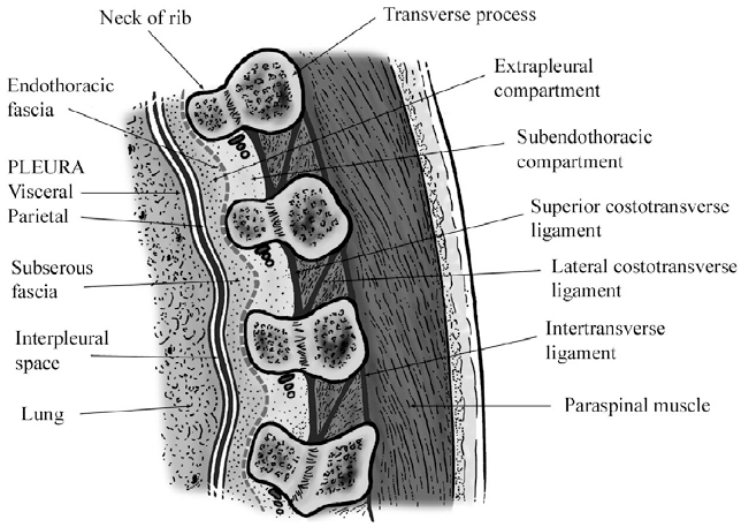
The thoracic paravertebral space is a wedge-shaped potential space, its depth greater medially when distended. It communicates with the cervical paravertebral space cephalad, but the psoas muscle probably limits direct communication with the lumbar paravertebral space caudally. Medially it is bound by the vertebral body, intervertebral disc and intervertebral foramen. Its anterolateral border is the parietal pleura and it communicates with the intercostal space laterally, beyond the tip of the transverse process. The posterior border is formed by the transverse process and the superior costotransverse ligament, which forms the most important structure to be traversed by the needle. This ligament joins the inferior aspect of the transverse process above with the superior aspect of the one below, and may be appreciated by a ‘click’ on advancement of the needle.

The contents include fat and extrapleural fascia, the segmental nerve branching into anterior and posterior primary rami, the sympathetic chain and rami communicantes, and radicular vessels. The nerve at this point may consist of rootlets and is devoid of a sheath, allowing good local anaesthetic penetration. The nerve should lie deep to the transverse process, protecting it from the needle.

The endothoracic fascia, the deep fascia of the thorax, is a fibroelastic structure dividing the paravertebral space into anterior and posterior compartments. It is closely applied to the anterior vertebral body, and laterally it contains the sympathetic chain anterior to it, the segmental nerve posterior to it. Catheter placement relative to this layer may determine the different patterns of spread observed with this block.



Anatomy of paravertebral space [11]



Anatomy of paravertebral space [11]

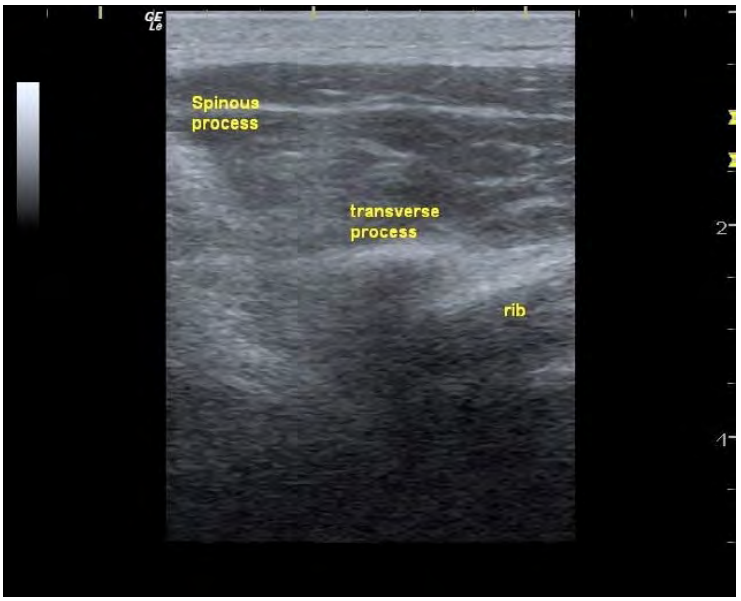
Surface anatomy

In the thoracic spine the superior aspect of the spinous process relates laterally to the transverse process of the vertebra below it, due to its steep downwards angulation. The tip of the transverse process is located ~2.5cm from the spinous process. This is the insertion point for the traditional approach to paravertebral blockade – the needle is inserted perpendicularly to skin until the transverse process tip is contacted, then 'walked off' into the paravertebral space.

Sonoanatomy

I usually start imaging with a linear probe at ~8MHz and change to a low frequency curved probe if imaging is inadequate. The curved probe provides a wider field of view which can help remind you of the midline and pleura, but at less resolution.

The transverse process projects posteriorly, and the costotransverse articulation is on its anterior aspect, forming a step in bony depth and angle to allow identification of the transverse process tip with ultrasound. With a transverse probe orientation, the acoustic shadow of these bony margins becomes deeper at the point where the transverse process joins the rib. It is important to distinguish the pleura from the acoustic shadow of bone – pleura moves with inspiration and some penetration of ultrasound occurs. The pleura can be distinguished from bone more easily on sagittal scanning – it is the deeper hyperechoic structure. Local anaesthetic injected into the paravertebral space should increase this depth between transverse process and parietal pleura.



Needle approaches to the paravertebral space

A number of US-guided approaches to the paravertebral space have been advocated, and no particular approach has been shown superior. Proximity to the neuraxis and lung require a good orientation to the anatomy and steep angles of insertion may make needle visibility difficult. Orientation to the transverse and spinous processes while needling is greatly helped by creating surface markings during your survey scan.

Ultrasound-assisted traditional approach

I would recommend this approach for beginners to ultrasound or paravertebral block, in obese patients or if there is subcutaneous emphysema making imaging difficult. The traditional approach had a good success rate and low risk of complications. A survey scan will define the location and depth of the transverse process tip for marking, and the depth to lung. When measuring distance, only light probe pressure should be used. Proceed with paravertebral blockade in the traditional way, ensuring the angle of needle insertion matches the angle of the ultrasound beam during the survey. I use a 16G Tuohy needle for this approach with the curved surface facing the pleura once the needle is angulated. Once the transverse process is contacted, walk off cephalad (or caudad) to a predetermined distance (10-15mm depending on size of patient/survey scan). Walking the needle cephalad is said to have a higher risk of pneumothorax and a second bone contact onto juxtaposed rib (see sagittal view above) may confuse the approach, but is my preferred approach to avoid the nerve root which lies on the caudad aspect. A click may be encountered crossing the superior costotransverse ligament or loss of resistance can be sought to assist with the endpoint, but these are not always felt. I deliver a bolus of local anaesthetic to distend the space before placing the catheter.

The advantage of this approach is its simplicity and not having to contend with needle visibility. The disadvantages are that displacement of the pleura cannot be observed, and resistance to feeding the catheter into the space (due to the steep angle) is common. Catheter displacement within 48 hours may result. The steep angle of insertion may also increase the risk of pneumothorax.

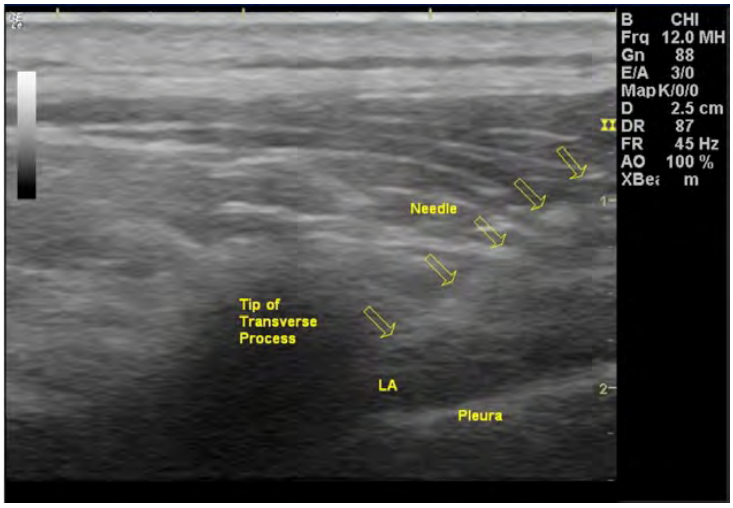
Lateral In-plane approach

This appears to be the preferred approach by other authors (and myself) for both single shot blocks and catheter insertion. Identification of the key landmarks is as described above.

The needle approach should be at least 2-3cm lateral to the tip of the transverse process to allow an angle suitable for needle visualisation. A sonographic Tuohy needle helps (such as Pajunk Tuohy Sono). When performing a survey scan, mark the tip of the transverse process and spinous process. It is usually possible to rotate the probe so that the transverse process and pleura are visible without the rib obscuring it. The needle approach is between these structures and injection under vision (by an assistant) to observe pleural displacement, confirming correct position.

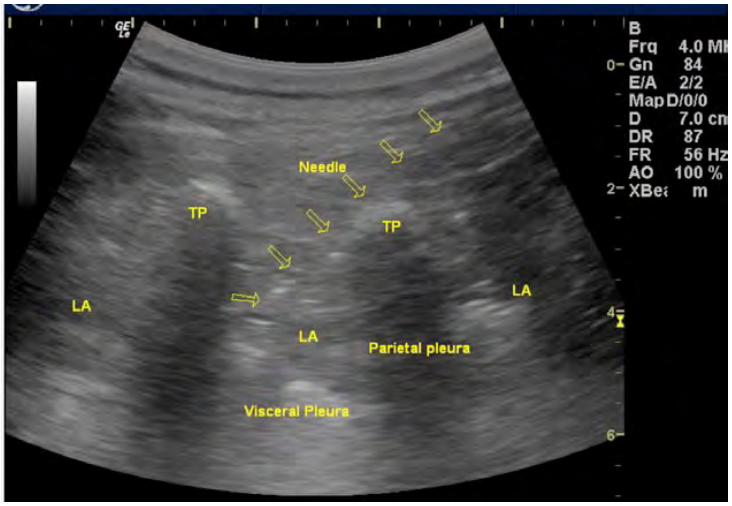
Care should be taken not to advance the needle far once it is in the acoustic shadow – it is pointing in the direction of the intervertebral foramen. It is also possible the catheter fed beyond the needle may enter the neuraxis, but has not been reported in the published case series [10].

An alternative approach is to slide the probe above or below the transverse process and insert needle tangential to the pleura, bevel up, moving the probe intermittently to reference the bony landmarks (personal communication, M Karmakar). This approach would not be pointing directly at the intervertebral foramen but requires more dexterity and interpretation of the anatomy.



Sagittal In-plane approach

Positioning the probe in a sagittal orientation 2-3cm lateral to the midline, per the above sonogram, clearly distinguishes bone and pleura. Pointing the probe slightly obliquely to the lateral side may improve visibility of the pleura which is reflected at this site. Between the transverse processes lies the superior costotransverse and intertransverse ligaments and below the paravertebral space. The difficulty I find with this approach is the angle of insertion becomes relatively steep to map a course between the bony landmarks and finish close to pleura, making needle visibility difficult. This may be helped by flexing the patient as much as possible, making the block slightly shallower and the bones further apart. The advantage is that spread can be observed in the adjacent acoustic windows and catheter insertion is not pointing toward the neuraxis.



Transverse scan with short-axis needle insertion

This is an extension of the traditional technique and would allow observation of the needle walking off the transverse process, but with the advantage of observing correct spread. The disadvantage is the difficulty of accurately locating the needle tip on the sonogram. I am yet to try this approach, see references [11].

Local anaesthetic delivery

Once the paravertebral space is located I load the space with 15-20ml of 0.25% bupivacaine before feeding the catheter.

Multiple level single shot injections require smaller volumes of more concentrated local anesthetic. The addition of adrenaline has been shown to reduce blood levels after the initial bolus and could indicate intravascular placement.

I generally prescribe 0.25% bupivacaine polybags for paravertebral use. Weaker solutions often do not provide sufficient analgesia, and motor block, sympathectomy, and urinary retention are unlikely to occur. Controversy exists over whether continuous infusion or repeated boluses should be used, but in my experience boluses often rescue an ineffective block. Assuming 2.5mg/kg every 6 hours is a safe maximum dose, I prescribe 1ml/kg 0.25% bupivacaine for this period, half given as a constant infusion and half given as an hourly bolus prn. For example, a 72kg adult would receive 6ml/h infusion plus 6ml nurse-initiated bolus hourly as required. When the patient is able to take oral opioid, patient-controlled paravertebral bolus may be used with or without continuous infusion. Patient controlled boluses should be used only after test boluses have not resulted in hypotension, which occurs infrequently.

Nursing education is important. I emphasise the need for paravertebral bolus prior to giving breakthrough opioid. Blood pressure should be checked after a nurse-initiated bolus.

Contraindications

The absolute contraindications to epidural insertion such as systemic sepsis, hypovolaemia, and use of anticoagulants tend to be relative contraindications for paravertebral insertion.

Particular to paravertebral insertion, contraindications may include decortication of the medial parietal pleura, fracture of the transverse process, empyema, and tumour invasion of the paravertebral space. Chest deformity such as kyphoscoliosis may predispose to neuraxial placement, and previous surgery or injury to the paravertebral area may predispose to pneumothorax

Complications

Complications are infrequent with paravertebral catheter insertion, 2.6-5% in published series.

Hypotension is quoted at 4.6%, and may indicate epidural placement or spread (especially with boluses >25ml), or unmasking of hypovolaemia.

Pneumothorax remains a feared complication, occurring in about 0.5% of cases using the traditional landmark technique. Its onset may be delayed. Pleural puncture is quoted at 1.1%. Suspect it if there is a sudden pain, cough, or unexpected easy feeding of catheter. If pleural puncture is suspected (without aspiration of air) a chest X-ray would be advisable. It is reasonable to expect the use of ultrasound to map the depth to bone and lung and ensure accurate needle placement will reduce this complication. The presence of an intercostal drain protects against this, making these patients more suitable for those new to the technique.

Intrathecal injection via a dural cuff has occurred, avoid medial needle angulation and always aspirate prior to injection.

Horner's syndrome may accompany a large bolus. The widest spread I have observed after 15ml 0.25% bupivacaine in the mid thoracic region was an ipsilateral ice block from C5 to L2!

Vascular injury to a radicular artery could occur but has not been reported. Vascular puncture is recognised in 6.8% of cases. Intravascular injection of local anaesthetic should always play

on the mind of the regionalist, slow injection and close monitoring should be employed, use adrenaline in the initial bolus and monitor the heart rate.

There is the potential for local anaesthetic toxicity as significant doses are often used for prolonged periods. Postoperative patients may be protected by α_1-acid glycoprotein, which could explain why toxicity is rare despite measured serum levels exceeding the toxic threshold. Reduce local anaesthetic doses in the frail or elderly and those with hepatic or renal impairment, and consider the use of ropivacaine or lignocaine in high risk situations.

There are no reports of neuralgias attributable to paravertebral puncture.

Acknowledgements

Many thanks to Peter Hebbard, who first described the use of ultrasound in TAP blockade, for providing the excellent technical drawings used in this article.

Thanks also to Manoj Karmakar for his patience and inspiring me to understand the sonoanatomy of the paravertebral space.

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Overview of techniques UGRA lower limb

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The aim of this review is to give an overview of common techniques for the ultrasound-guided blockade of the lower limb, and in particular, the femoral, saphenous, and sciatic nerve blocks.

Ultrasound Guided Femoral Nerve Block

Blockade of the femoral nerve results in anaesthesia of the anterior and medial thigh down to and including the knee, as well as a variable strip of skin on the medial leg and foot. Typically this block is performed in the supine position, with the bed or table flattened to maximise access to the inguinal area. While palpation of a femoral pulse is a useful landmark, it is not required, as the artery is quickly visualised by placement of the transducer transversely on the inguinal crease followed by slow movement laterally or medially. If nerve stimulation is to be used at the same time, exposure of the thigh and patella are required in order to observe for the appropriate motor responses.

A linear transducer is placed transversely on the proximal thigh, at the level of the inguinal crease (**Figure 1**). Orientation begins with identification of the large, pulsating femoral artery; if not immediately visible, sliding the transducer medially and laterally will eventually bring the vessel into view. Immediately lateral to the vessel, and deep to the iliacus fascia is the femoral nerve, which is typically hyperechoic and roughly triangular or oval in shape (**Figure 2**). The nerve is wedged in between the iliacus muscle and the femoral artery, and is often best seen at the level of the artery's bifurcation. This can be elicited by moving the transducer caudad and cephalad along its course. Other structures that can be visualised are the femoral vein (medial to the artery) and occasionally the fascia lata (superficial in the subcutaneous layer). The femoral nerve is typically visualised at 2-4 cm depth and identification is often made easier by slightly tilting the transducer cranially or caudally. This helps to "brighten" up the nerve and make it appear distinct from the background (the principle of "anisotropy").

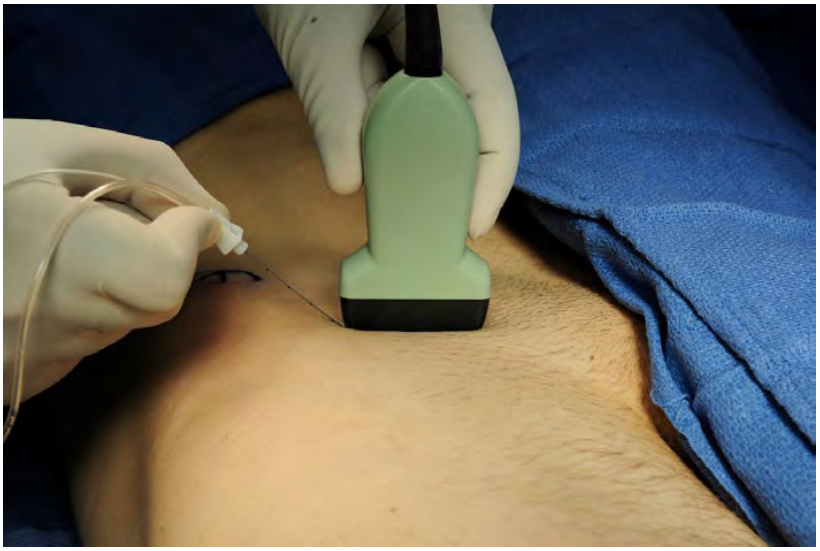


Figure 1. Transducer and needle position for ultrasound guided R) femoral nerve block (in-plane)

The goal is to place the needle tip immediately adjacent to the femoral nerve, below the fascia iliaca, and deposit local anaesthetic until spread beside the nerve is documented with ultrasound. With the patient in the proper position, the skin is disinfected and the transducer positioned so as to identify the femoral artery and nerve. Once identified, a skin wheal is made on the lateral aspect of the thigh 1 cm away from the lateral edge of the transducer. The needle is then inserted in-plane in a lateral-to-medial orientation, and advanced towards the femoral nerve (**Figure 3**). If nerve stimulation is used (0.5 mA, 0.1 msec), the passage of the needle through the fascia iliaca and contact of the needle tip with the femoral nerve is usually associated with a motor response of the quadriceps. Once the needle tip is witnessed adjacent (either below or lateral) to the nerve, and after careful aspiration, 1-2ml of local anaesthetic is injected to confirm the proper injection site. When injection of the local anaesthetic does not appear to result in a spread beside the femoral nerve, the needle should be withdrawn and repositioned.

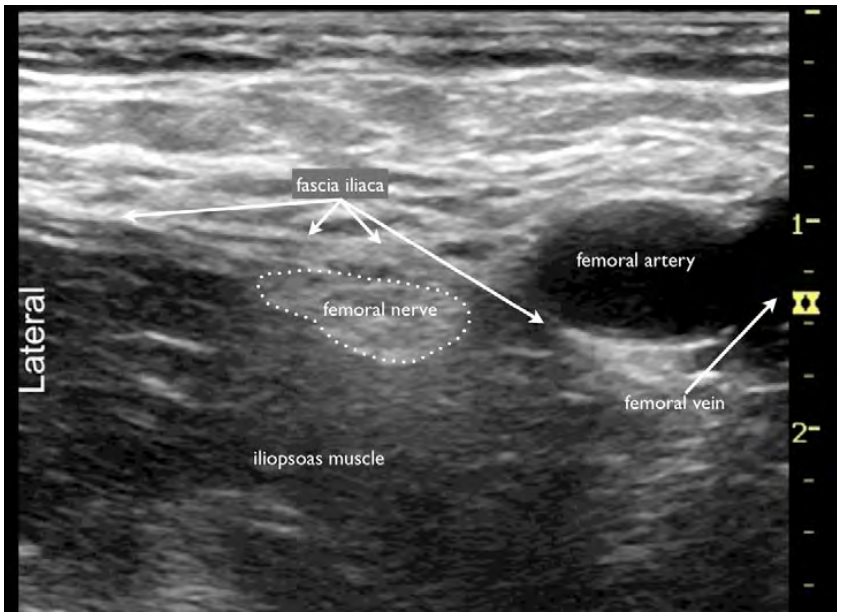


Figure 2. Sonoanatomy of the femoral nerve and surrounding structures at the level of the inguinal crease.

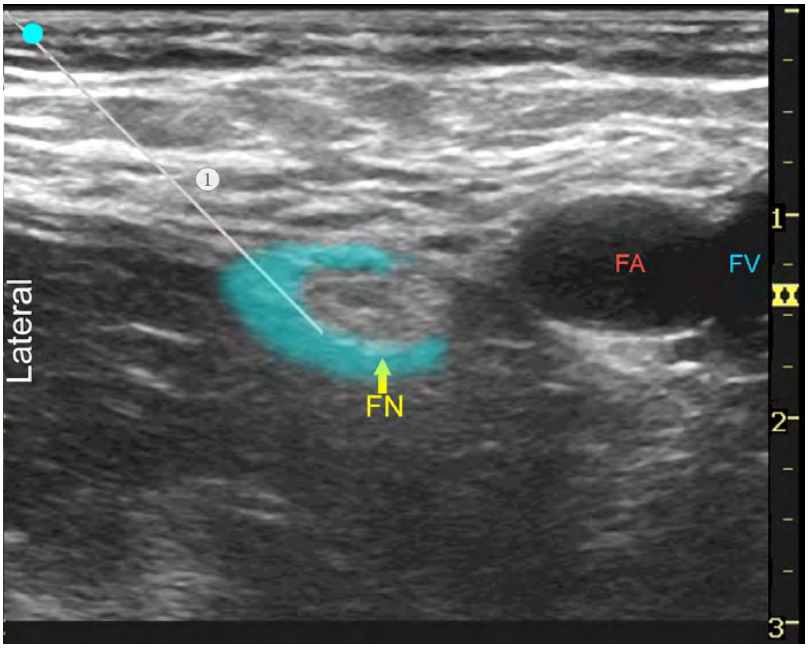


Figure 3. Sonoanatomy of the femoral nerve and surrounding structures at the level of the inguinal crease.

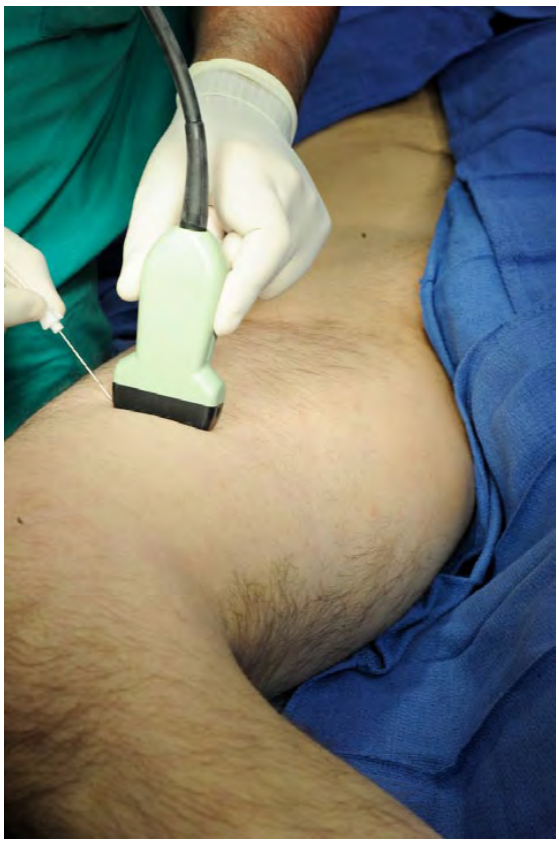
In an adult patient, 15-20 ml of local anaesthetic is usually adequate for successful blockade, but less volume may be sufficient for proper spread. While a single injection of such volumes of local anaesthetic suffices, it may be beneficial to inject 2-3 smaller aliquots at different locations (i.e. posterior and lateral) to improve the speed of onset of the block.

Ultrasound-Guided Saphenous Nerve Block

The saphenous nerve is the terminal sensory branch of the femoral nerve, and supplies the medial aspect of the leg down to the ankle and foot. While it can be used as a stand-alone block for superficial procedures on this area, it is most useful as a supplement to a sciatic block for foot and ankle procedures that will involve the medial territory. For many practitioners, the use of ultrasound-guidance has improved the success rates compared with field blocks below the knee and blind trans-sartorial approaches. The ultrasound-guided technique described here is easy, quick to perform and very reliable.

Any position that allows comfortable placement of the ultrasound transducer and needle advancement is appropriate. While prone and lateral approaches are possible, typically this block is performed in the supine position, with the thigh abducted and externally rotated in order to access the medial thigh (**Figure 4**). If difficulty confirming the sartorius muscle is encountered, exposure of the entire thigh in order to scan down from above is sometimes required.

Figure 4. Transducer and needle position for ultrasound guided R) saphenous nerve block



The sartorius muscle, which descends laterally to medially across the anterior thigh, forms a “roof” over the adductor canal in the lower half of the thigh. This appears as an oval or “feather”-shaped muscle directly beneath the subcutaneous layer of adipose tissue (**Figure 5**). This can be confirmed by visualising the pulsating femoral artery directly beneath the muscle. The sides of the triangular canal are formed by the vastus medialis laterally and adductor longus or magnus medially (depending on how proximal or distal the scan is). The saphenous nerve is infrequently seen on the ultrasound image, but can sometimes be visualised as a small, round hyperechoic structure medial to the artery. A femoral vein accompanies the artery and saphenous nerve, which is typically visualised at 2-3 cm depth.

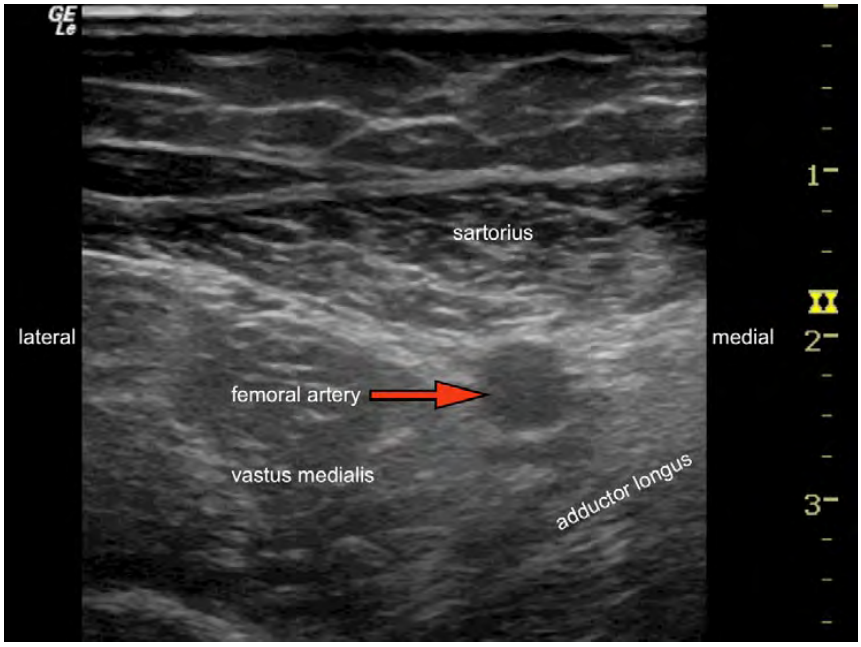


Figure 5. Sonoanatomy of the subsartorial area at the juncture of the proximal two thirds and distal one third of the thigh. Note that the saphenous nerve is not obviously apparent, and the pressure applied by the transducer has collapsed the femoral vein.

With the patient in the proper position, the skin is disinfected and the transducer placed on the anteromedial thigh, approximately one third of the distance up the thigh from the knee joint. If the artery is not immediately obvious, trace the femoral artery caudally from the inguinal crease. Once identified, a skin wheal is made on the medial aspect of the transducer. The needle can then inserted out-of-plane and advanced towards either side of the femoral artery. Once the needle tip has "popped" through the back wall of the sartorius and is visualised medial to the artery, and after careful aspiration, 1-2 ml of local anaesthetic is injected to confirm the proper injection site. When injection of the local anaesthetic does not appear to result in spread beside the femoral artery, additional needle repositions and injections may be necessary.

In an adult patient, 5-10 ml of local anaesthetic is usually adequate for successful blockade. Since the saphenous is a purely sensory nerve, high concentrations of local anaesthetic are usually not required, and may only serve to delay ambulation.

Ultrasound-Guided Sciatic Blocks

Ultrasonography has greatly expanded the options that practitioners have for performing sciatic nerve blocks, as the nerve can be imaged at several key locations. Blockade of the sciatic nerve results in anaesthesia of the entire lower limb below the knee, both motor and sensory, with the exception of a variable strip of skin on the medial leg and foot, which is the territory of the saphenous nerve, a branch of the femoral nerve. In general, the more proximal the approach, the more motor block of the hamstring muscles one will achieve; the skin of the posterior aspect of the thigh is supplied by the posterior cutaneous nerve of the thigh, which has its origin from the sciatic nerve more proximal than the subgluteal approach. It is therefore unreliably blocked, but is of little clinical consequence.

Ultrasound-Guided Subgluteal Sciatic Nerve Block

The name of this approach has caused some confusion as it implies that the needle insertion is distal to the gluteal crease; in fact, it refers to the fact that the nerve is blocked while deep to

the gluteus maximus muscle. Here the nerve is easily identified in a predictable anatomical arrangement between two bony landmarks and beneath a well-defined muscle plane. The use of ultrasound eliminates the need for the geometry and measurements that are frequently required for the classic landmark based approaches. In addition, the palpation of often ill-defined landmarks such as the posterior superior iliac spine are no longer required, which may reduce the amount of time required to prepare for and perform the block.

Any position that allows comfortable placement of the ultrasound transducer and needle advancement is appropriate. Typically for the subgluteal block, this involves placing the patient in the lateral decubitus position, the prone position, or any intermediate position between the two that allows access to the buttock. The hip and knee are somewhat flexed. If nerve stimulation is to be used at the same time, exposure of the calf and foot are required in order to observe for motor responses. The round, bony prominences of the greater trochanter and ischial tuberosity are palpated, and, if desired, marked with a skin marker. Scanning is begun in the depression between the two bones (**Figure 6**).

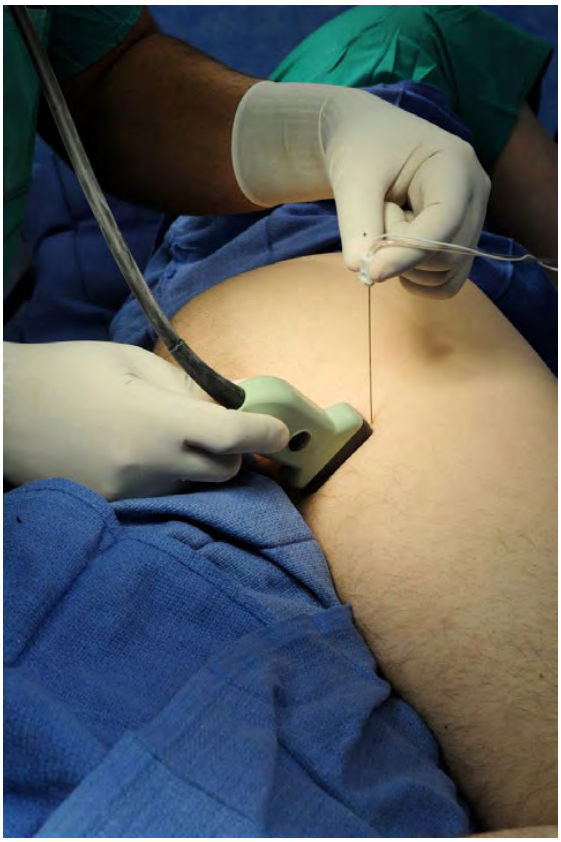


Figure 6. Transducer and needle position for ultrasound guided R) subgluteal sciatic nerve block.

While a linear transducer can occasionally be used for thin patients, the curvilinear transducer permits visualisation of a wider field. For example, the ischial tuberosity and greater trochanter are rarely seen on the same image with the linear transducer, but are almost always seen on the same image with the curvilinear probe.

The sciatic nerve at the subgluteal level is visualised in its short axis between the two hyperechoic bony prominences of the ischial tuberosity and the greater trochanter of the femur (**Figure 7**). The gluteus maximus muscle is seen as the most superficial muscular layer bridging the two bones, and is usually several centimeters thick. The sciatic nerve is located immediately deep to the gluteus maximus, superficial to the quadratus femoris muscle. It is often slightly closer to the medial (ischial tuberosity) aspect than the lateral (greater trochanter). At this location in the thigh, it is seen as an oval or roughly triangular, hyperechoic structure.

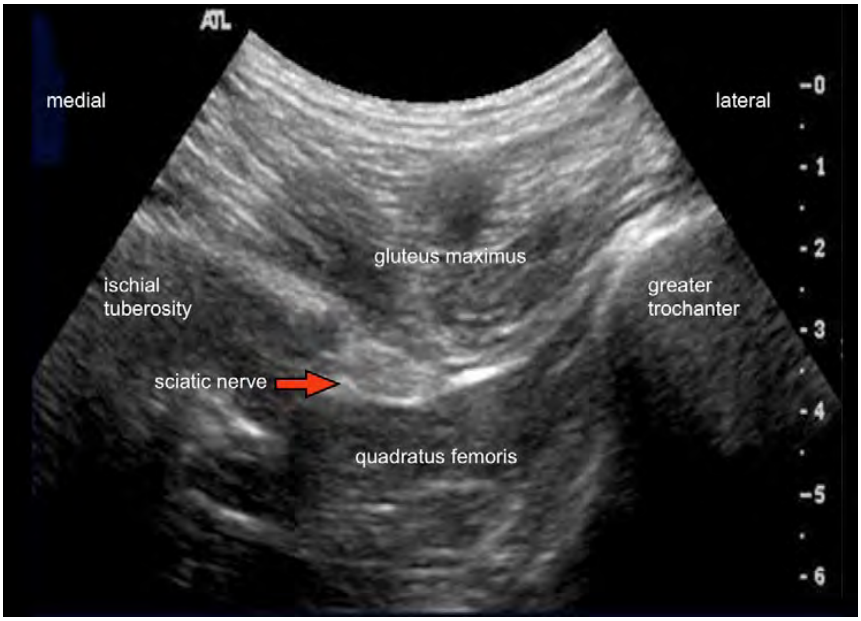


Figure 7. Sonoanatomy of the subgluteal sciatic nerve and surrounding structures.

With the patient in the proper position, the skin is disinfected and the transducer positioned so as to identify the sciatic nerve. If the nerve is not immediately apparent, toggling or tilting the transducer proximally or distally can often help to improve the contrast and bring the nerve "out" of the background of the musculature. Alternatively, sliding the transducer slightly proximally or distally may improve the quality of the image, and allow for better visualisation. Once identified, the needle is inserted in-plane from the lateral aspect of the transducer, and advanced towards the sciatic nerve. If nerve stimulation is used (0.5 mA, 0.1 msec), the passage of the needle through the posterior fascial plane of the gluteus maximus is often associated with the a motor response of the calf or foot. Once the needle tip is witnessed adjacent to the nerve, and after careful aspiration, 1-2 ml of local anaesthetic is injected to document the proper injection site.

In an adult patient, 15-20 ml of local anaesthetic is usually adequate for successful blockade. While a single injection of such volumes of local anaesthetic suffices, it may be beneficial to inject 2-3 smaller aliquots at different locations to ensure spread of the local anaesthetic solution around the sciatic nerve.

Ultrasound-Guided Anterior Sciatic Nerve Block

The anterior sciatic block is one that can be very useful, particularly in those patients who cannot be turned to the lateral position for reasons of pain, trauma, external fixation devices, etc. Likewise, it is well-suited to patients who require postoperative blocks for pain, such as those patients who have posterior knee pain following total knee arthroplasty. Ultrasonography adds the benefit of not requiring the palpation of a femoral pulse, or the use of geometry for identification of the skin puncture point. In addition, the ultrasound-guided approach reduces the risk of femoral arterial puncture compared to the landmark-based approach. The actual scanning and needle insertion are performed on the anteromedial aspect of the proximal thigh, rather than the anterior surface, and requires a degree of abduction and external rotation of the thigh. For this reason, this block may not be appropriate for those patients that cannot perform these manoeuvers. This block is not particularly well-suited to continuous catheters, as the procedure involves a large needle traversing a large amount of muscle (causing pain and possibly haematomas), as well as an awkward catheter location (medial thigh).

This block is performed in the supine position. The hip is abducted approximately 30 degrees, and the thigh externally rotated in order to facilitate transducer and needle placement. The hip and knee are somewhat flexed. If nerve stimulation is to be used at the same time, exposure of the calf and foot are required in order to observe for motor responses. It is useful to expose the entire thigh in order to appreciate the distance from the groin and knee.

The sciatic nerve is imaged at the junction of the proximal one third and distal two thirds of the thigh. At this location, a curvilinear transducer placed over the anteromedial aspect of the thigh (**Figure 8**) will reveal musculature of all three fascial compartments of the thigh: anterior, medial and posterior. Beneath the superficial sartorius muscle is the femoral artery, and deep and medial to this vessel is the profunda femoris artery (**Figure 9**). These can both be highlighted with colour Doppler for orientation. The femur can be easily seen as a hyperechoic rim beneath the vastus intermedius. Medial to the femur is the bulk of the adductor magnus muscle, separated by a fascial plane from the semimembranosus and semitendinosus muscles. The sciatic nerve can be visualised as a hyperechoic flattened oval sandwiched between these two muscle planes. The nerve is typically visualised at a depth of 7-8 cm. If the nerve is not immediately apparent, toggling or tilting the transducer proximally or distally can often help to improve the contrast and bring the nerve "out" of the background of the musculature. Alternatively, sliding the transducer slightly proximally or distally may improve the quality of the image, and allow for better visualisation. Once identified, the needle is inserted in-plane from the medial aspect of the thigh, and advanced towards the sciatic nerve (**Figure 10**). Once the needle tip is witnessed adjacent to the nerve, and after careful aspiration, 1-2 ml of local anaesthetic is injected to confirm the proper injection site. In an adult patient, 15-20 ml of local anaesthetic is usually adequate for successful blockade.

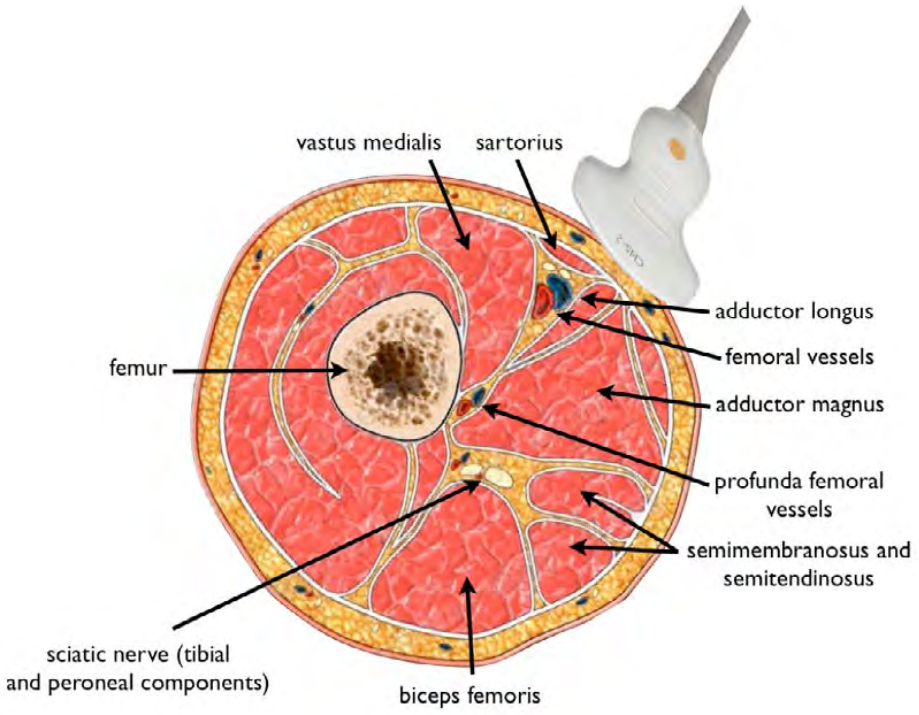


Figure 8. Transducer position for ultrasound guided anterior sciatic nerve block.

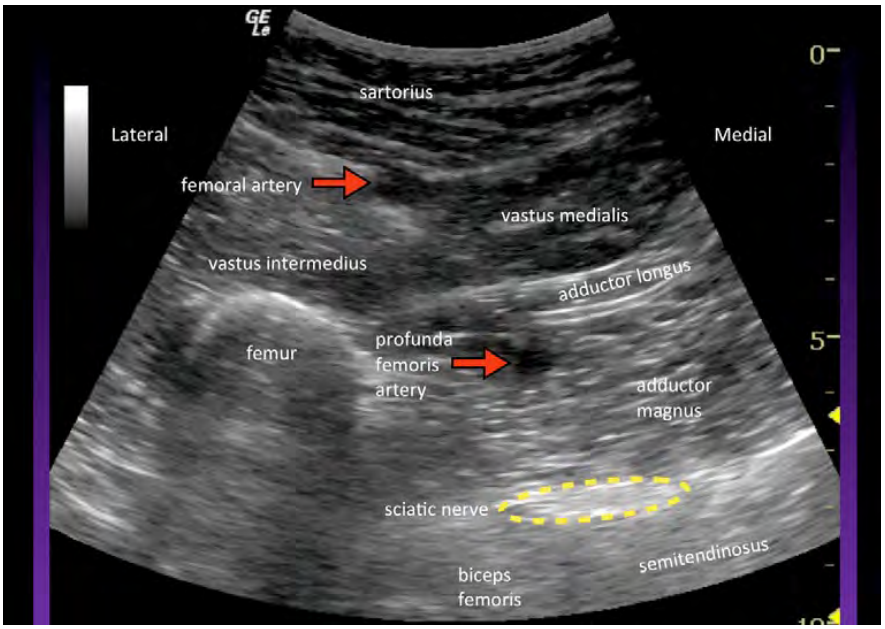


Figure 9. Sonoanatomy of the anterior sciatic nerve block with surrounding structures.

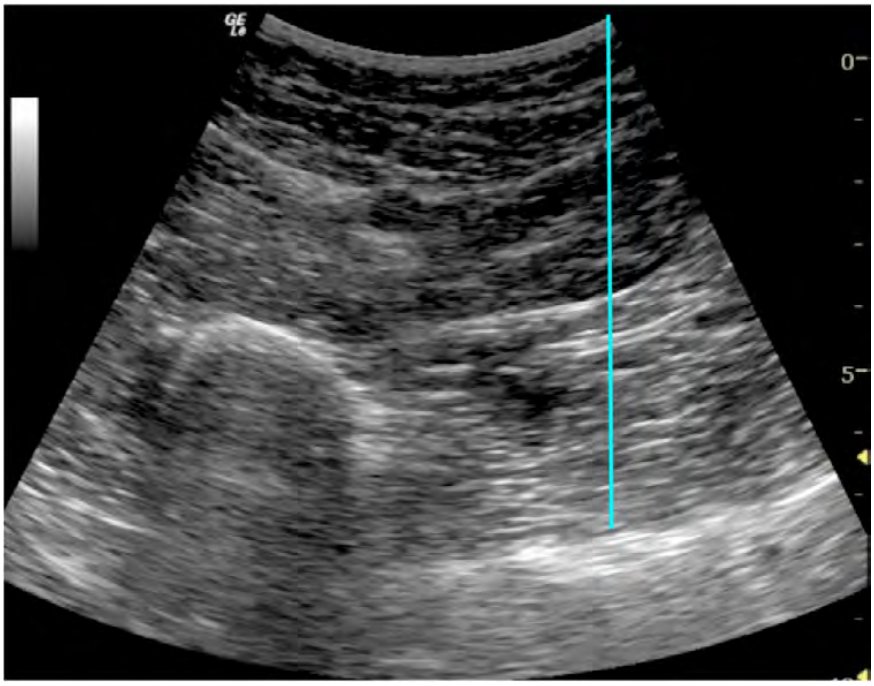


Figure 10. Projected medial in-plane needle path for the anterior sciatic nerve block.

Ultrasound-Guided Popliteal Sciatic Nerve Block

The sciatic block above the popliteal fossa benefits from ultrasound-guidance in several ways. The anatomy of the sciatic nerve as it approaches the popliteal fossa can be variable, and the division into tibial nerve and common peroneal nerve can occur at any

distance from the crease. Knowledge of where these nerves lie exactly in relation to each other can ensure proper spread of local anaesthetic around all of the elements of the sciatic nerve. Moreover, with nerve-stimulator based techniques, larger volumes (e.g. >40 ml) of local anaesthetic are often required to hedge against block failure. A clear reduction in local anaesthetic volume can be achieved with ultrasound guidance, as the injection can be halted once circumferential spread is documented. The two approaches to the popliteal sciatic block that are most common are the lateral (supine) approach and the prone approach. Both are discussed here, as only the patient position and needle path differs between the two techniques.

With both the posterior and the lateral approach, the transducer position is identical; thus, the sonographic anatomy appears the same. However, note that while the image appears the same, there is a 180 degree difference in *patient* orientation, so that with lateral approach (patient supine with ultrasound beam aiming at the ceiling), structures on the upper half of the image are actually closer to the floor. Beginning with the transducer in the transverse position at the popliteal crease (**Figure 11**), the popliteal artery is identified at a depth of approximately 2-4 cm (**Figure 12**). The popliteal vein accompanies the artery but is less well-visualised in some individuals. On either side of the artery are the biceps femoris muscles (lateral) and the semimembranosus and semitendinosus muscles (medial). Superficial (i.e. towards the skin surface) and lateral to the artery is the tibial nerve, seen as a hyperechoic oval or round structure with a stippled or honeycomb pattern on the interior. If difficulty in identifying the nerve is encountered, the patient may be asked to dorsiflex and plantar flex the ankle, which makes the nerve rotate or “dance” in relation to its surroundings. Once the tibial nerve is identified, an attempt can be made to visualise the common peroneal nerve, which is located even more superficial and more lateral to the tibial nerve. The peroneal nerve may not be apparent at this level. The transducer should then be slid proximally until the tibial and peroneal nerves are visualised coming together to form the complete sciatic nerve, (**Figure 13**). This usually occurs at a distance of 5-10 cm from the popliteal crease, but may occur very close to the crease or (less commonly) more proximally in the thigh. As the transducer is moved proximally the popliteal vessels move anteriorly (i.e. deeper) and therefore become less visible. Adjustments in depth, gain and direction of the ultrasound beam should be made to keep the nerve visible at all times. The sciatic nerve is typically visualised at a depth of 3-4 cm.

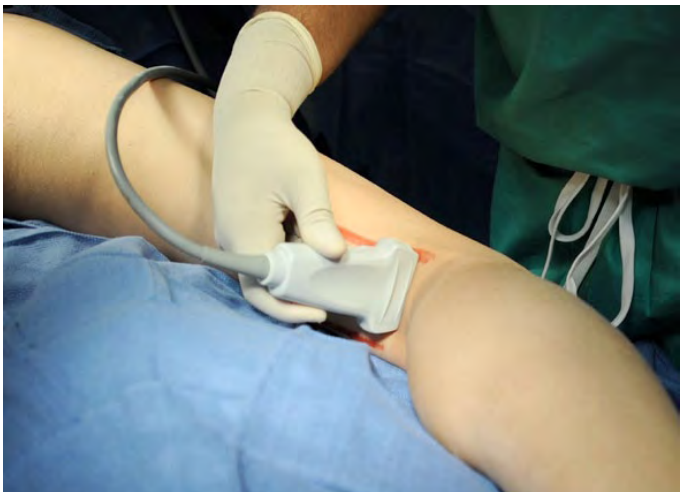


Figure 11. Transducer position for ultrasound guided popliteal sciatic nerve block.

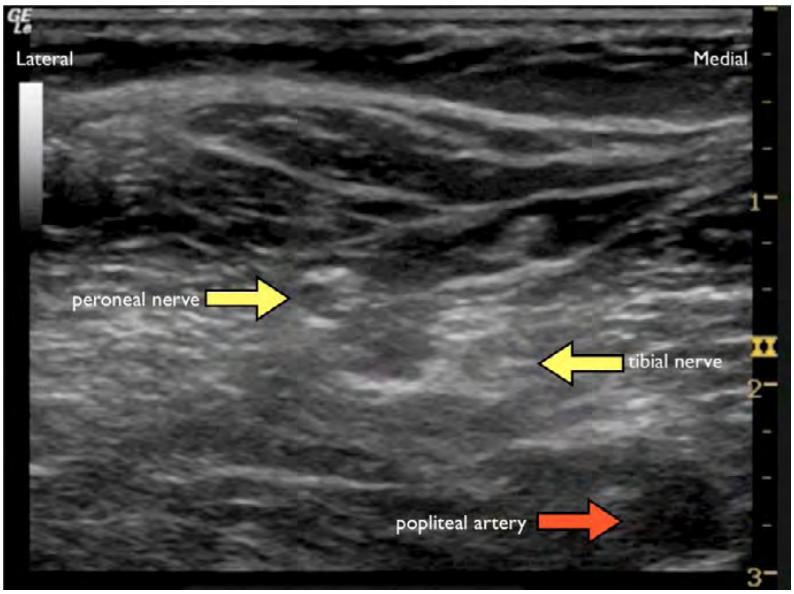


Figure 12. Sonoanatomy of the tibial and common peroneal nerves immediately proximal to the popliteal crease. Note the separation of the two nerves.

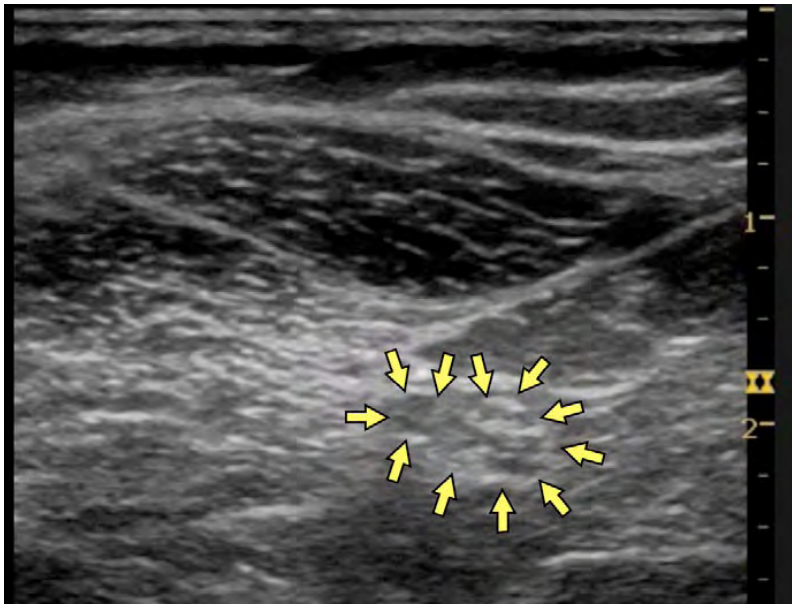


Figure 13. Sonoanatomy of the tibial and common peroneal nerves 6 cm proximal to the popliteal crease. The two nerves have merged within a common epineurial sheath.

Lateral Approach

This block is performed in the supine position. Sufficient space must be made to accommodate the transducer beneath the knee and thigh - this can be done either by resting the foot on an elevated footrest, or flexing the knee while an assistant stabilises the foot and ankle on the bed. If nerve stimulation is to be used at the same time, exposure of the calf and foot are required in order to observe for motor responses. The goal is to place the needle tip immediately adjacent to the sciatic nerve and deposit local anaesthetic until spread around the nerve is documented with ultrasound. Alternatively, if both the common peroneal and tibial nerves are visualised well, separate blocks can be made for both of these.

With the patient in the proper position, the skin is disinfected and the transducer positioned so as to identify the sciatic nerve. Once identified, a skin wheal is made on the lateral aspect of the thigh 2-3 cm above the lateral edge of the transducer, in order to reduce the acuity of the needle angle with respect to the beam (i.e. the needle and the transducer surface should be

close to parallel). The needle is then inserted in-plane in a horizontal orientation from the lateral aspect of the thigh, and advanced towards the sciatic nerve. Once the needle tip is witnessed adjacent to the nerve, and after careful aspiration, 1-2 ml of local anaesthetic is injected to confirm the proper injection site (**Figure 14**). In an adult patient, 20-30 ml of local anaesthetic is usually adequate for successful blockade, but less volume may be sufficient for proper circumferential spread.

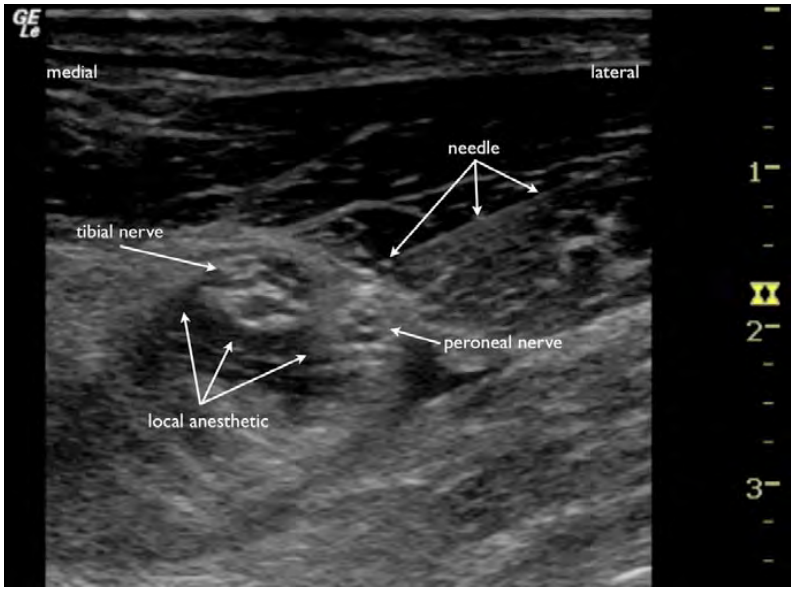


Figure 14. Sonoanatomy of the popliteal nerve block. The needle is approaching from the lateral side and local anaesthetic can be seen spreading deep to the tibial and peroneal nerves.

Prone Approach

This block is performed in the prone position, with the legs slightly abducted. A small footrest is often useful to facilitate identification of a motor response if nerve stimulation is used. It also relaxes the hamstring tendons, making transducer placement and manipulation easier. The goal is to place the needle tip immediately adjacent to the sciatic nerve and deposit local anaesthetic until spread around the nerve is documented with ultrasound. Alternatively, if both the common peroneal and tibial nerves are visualised well, separate blocks can be made for both of these.

With the patient in the prone position, the skin is disinfected and the transducer positioned so as to identify the sciatic nerve. Once identified, a skin wheal is made immediately caudad or cephalad to the transducer. The needle is then inserted out-of-plane at a steep angle, and advanced towards the sciatic nerve (**Figure 15**). Small injections (0.5-1 ml) of local anaesthetic as the needle travels towards the nerve will help to identify the location of the needle tip, as it may not be clearly visible with the out-of-plane approach. Once the needle tip is confirmed to be adjacent to the nerve by a similar small injection of local anaesthetic, the syringe is gently aspirated and the local anaesthetic deposited. Redirection to both the medial and lateral sides of the sciatic nerve is frequently required to ensure adequate circumferential spread. Local anaesthetic volumes of 20-30 ml are frequently required to ensure adequate blockade, but less may be used if spread is deemed appropriate by ultrasound.

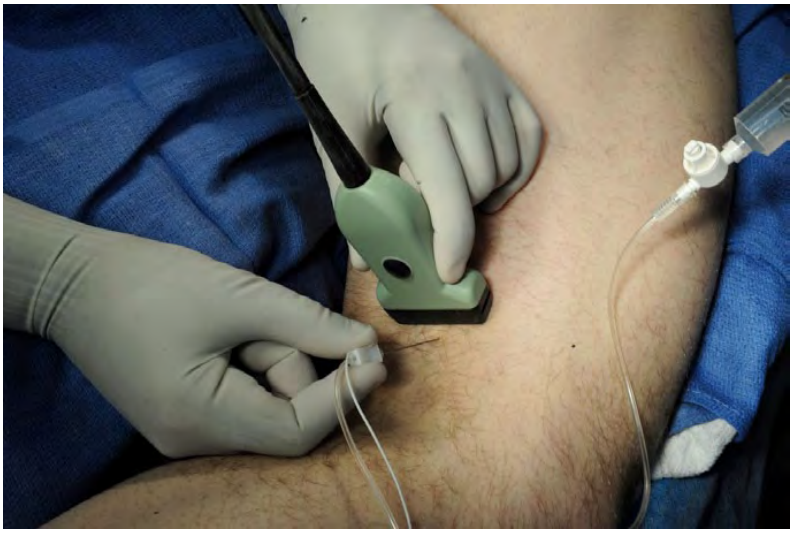


Figure 15. Transducer position for the out-of-plane ultrasound guided popliteal sciatic nerve block in the prone position.

Ultrasound-Guided Continuous Femoral and Sciatic Nerve Blocks

The performance of an US-guided continuous femoral or sciatic nerve block consists of three phases – needle placement, catheter advancement and securing of the catheter. The needle is again typically inserted in-plane in the same manner as the single-injection technique, and with the same goal of having the needle tip rest adjacent to the nerve. Once in the correct location, a small aliquot of local anaesthetic (5-8 ml) is administered. This serves to ensure adequate distribution of the local anaesthetic as well as to make the advancement of the catheter easier. The second phase of the procedure involves maintaining the needle in the proper position and inserting the catheter 2-4 cm into the newly-created space surrounding the femoral or sciatic nerve. Insertion of the catheter can be accomplished by either single operator or with an assistant. Since the catheter is not usually seen on the ultrasound image, it is best to infer the tip location with the injection of fluid (local anaesthetic or saline) via the catheter while observing the ultrasound screen. The colour Doppler function is also useful to determine catheter tip location.

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Ultrasound-Guided Femoral Block

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Overview of ultrasound guided regional anaesthesia of the upper limb

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Introduction

Ultrasound guidance has enabled visualisation of neural structures thereby facilitating precise, reliable upper limb blockade. Ultrasound guided regional anaesthesia (UGRA) is now a viable alternative to general anaesthesia on a worldwide basis. Central to the practice of UGRA is a thorough knowledge of relevant clinical anatomy. As significant inter-individual anatomical variation exists, ultrasonography permits real-time examination of clinical anatomy. The modern anaesthetist is now armed with a powerful tool to provide bespoke, individualised regional anaesthesia.

In my talk, I will concentrate on some of the common variations encountered on examination of the brachial plexus at the level of the interscalene groove, the supraclavicular fossa and the axilla. Interpretation (or misinterpretation) of the image obtained may significantly influence block outcome. The talk will also include nerves of the forearm, which exhibit the least variability in terms of location and immediate anatomical relations.

Interscalene Groove

The brachial plexus is formed by the C5-T1 nerve roots, which exit their respective intervertebral foramina, and enter the posterior triangle of the neck between the anterior and middle scalene muscles. Here they form the trunks: upper (C5&6); middle (C7); and lower (C8&T1). Invested in a layer of pre-vertebral fascia, the brachial plexus travels in close and variable relation to the anterior and middle scalene muscles toward the supraclavicular fossa.

When imaged at the level of the C7 transverse process, a number of patterns of neural layout can be identified. Figure 1 summarises three of the common variations seen.

A: The superior, middle and inferior trunks are all visualised within the groove and lie within close relation to each other.

B: One of the trunks (usually the superior trunk), has a variable intramuscular course, usually within the scalenus anterior muscle.

C: The inferior trunk lies deep to the scalenus anterior muscle.

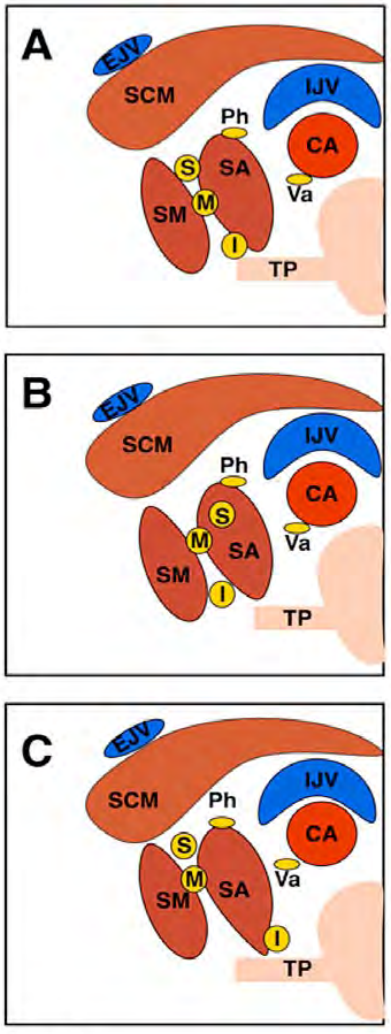

Figure 1

Interscalene Brachial Plexus

SCM = Sternocleidomastoid Muscle
SA = Scalenus Anterior Muscle
SM = Scalenus Medius Muscle
CA = Carotid Artery
IJV = Internal Jugular Vein
EJV = External Jugular Vein
TP = C7 Transverse Process
Ph = Phrenic Nerve
Va = Vagus Nerve

Interscalene block is useful for anaesthesia and analgesia for shoulder and proximal humerus surgery. The spatial arrangement of the brachial plexus trunks may significantly influence local anaesthetic spread and block success.

Supraclavicular Fossa

Supraclavicular block is useful for hand, forearm and elbow surgery. At the level of the supraclavicular fossa, the brachial plexus trunks have divided into anterior and posterior divisions, and given the dorsal scapular nerve, suprascapular nerve and nerve to subclavius. The plexus lies in close relation to the subclavian artery, first rib and pleura (Figure 2 A). At this level the descending (dorsal) scapular artery arises from the subclavian artery. This artery may be very prominent in athletes and manual workers. When visualised, it appears divide the supraclavicular plexus into two compartments (Figure 2B). Spread of local anaesthetic injectate may be limited by this phenomenon, illustrating the need to identify each of the components of the plexus and the immediate relations.

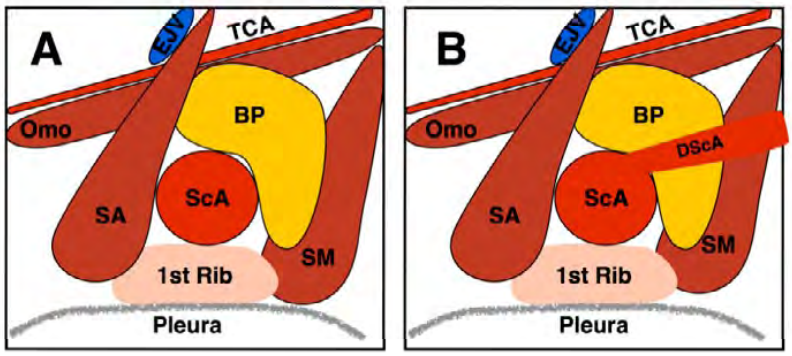

Figure 2

Supraclavicular Brachial Plexus

SA = Scalenus Anterior Muscle
SM = Scalenus Medius Muscle
ScA = Subclavian Artery
DScA = Descending Scapular Artery
EJV = Internal Jugular Vein
Omo = Inferior Belly Omohyoid Muscle
TCA = transverse Cervical Artery
BP = Divisions of Brachial Plexus

x

Axillary brachial plexus block is useful for forearm, wrist and hand surgery. The terminal nerves of the brachial plexus lie in close relation to each other and the axillary vasculature.

- Median nerve arises from the lateral and medial cords
- Ulnar nerve from the medial cord
- Radial nerve from the posterior cord
- Musculocutaneous nerve from the lateral cord

The arrangement of the nerves of the axillary brachial plexus around the axillary artery exhibits very significant inter-individual variability. Figure 3 illustrates many of the common variations encountered during axillary block.

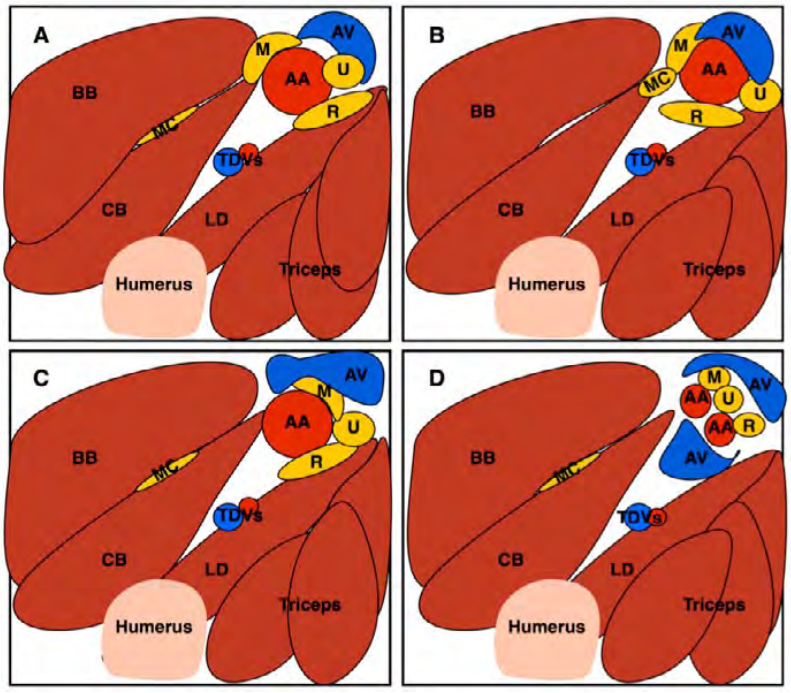

Figure 3
Axillary Brachial Plexus

BB = Biceps Brachii
CB = Coracobrachialis
LD = Latissimus Dorsi
AA = Axillary Artery(ies)
AV = Axillary Vein(s)
TDVs = Thoracodorsal Vessels
M = Median Nerve
U = Ulnar Nerve
R = Radial Nerve
MC = Musculocutaneous Nerve

A. This may be thought of as the standard arrangement of nerves, vessels and surrounding musculature.

B. The musculocutaneous nerve may lie in close relation to the median nerve (lateral cord).

C. The axillary vein may surround the neural contents, pushing them clockwise around the axillary artery.

D. There may be a duplex arterial system in the axilla (6-8%) with resultant alterations in nerve layout.

These represent the principal variations commonly encountered in my clinical practice.

Forearm Nerves (Figure 4)

Peripheral nerve block at the level of the forearm is a useful adjunct to plexus blockade. The nerves of the forearm have relatively consistent relations at fixed points. At the level of the antecubital fossa, the median nerve can be visualised as a honeycomb structure medial to the brachial artery (Figure 4A). The radial nerve at this same level has divided into a superficial branch and a deep (posterior interosseous) branch. It can be seen like a pair of eyes looking out between the brachioradialis and brachialis muscles (Figure 4B). The ulnar nerve is found in the medial forearm, between the flexor digitorum superficialis and profundus muscles, in close relation to the ulnar artery (Figure 4C).

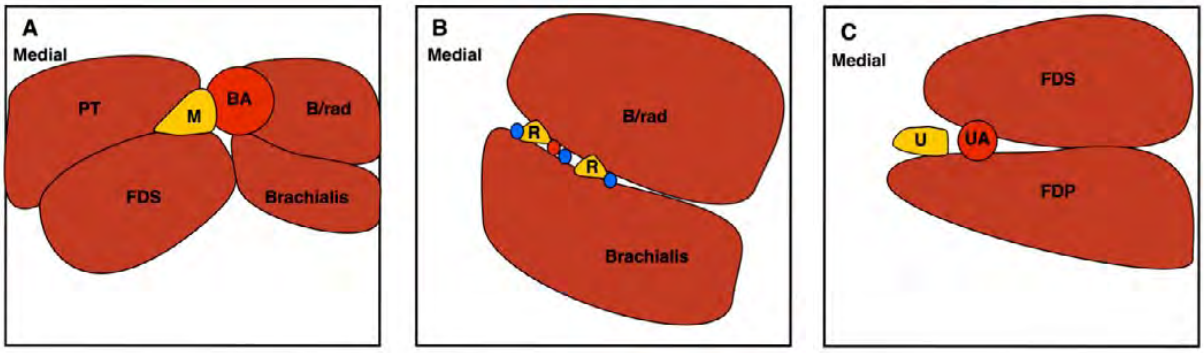

Figure 4
Terminal Nerves in the forearm

PT = Pronator Teres
FDS = Flexor Digitorum Superficialis
FDP = Flexor Digitorum Profundus
B/rad = Brachioradialis
BA = Brachial Artery
M = Median Nerve
U = Ulnar Nerve
R = Radial Nerve

Forearm techniques can be used as the 'rescue' block for failed or insufficient plexus block. It can also be used to deposit long acting local anaesthetic for post-operative analgesia when rapid return proximal limb function is desirable (e.g. axillary block for palmar fasciectomy using lignocaine, with bupivacaine deposited at the ulnar nerve in the forearm for post-operative analgesia). Finally hand surgery to discrete areas not requiring an arm tourniquet (K-wire 5th metacarpal) may be performed entirely using a forearm single nerve block (ulnar nerve).

Summary

Clinician acceptance that the 'TEXTBOOK' description of anatomy does not necessarily exist will permit appropriate interpretation of the ultrasound image acquired during UGRA. Correct image interpretation improves the likelihood of successful block outcome. Ultrasonography permits the identification of all anatomical types, enabling individualised, safe and effective peripheral nerve block.

Publishing in ultrasound-guided regional anaesthesia: What are the editors thinking?

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Where did it all start?

Perhaps the first publication to describe an ultrasound-guided nerve block was the article by La Grange and colleagues that appeared in the *British Journal of Anaesthesia* as long ago as 1978 [1]. This paper had the hallmark of an article that was almost bound to be published; it described the use of ultrasound (Doppler) to locate the subclavian artery and place effective supraclavicular brachial plexus blocks, and as such, this was something completely novel and therefore very publishable. I find it fascinating that it took another decade before further descriptions started appearing. However, from the middle part of the 90's onwards a large number of publications started appearing describing various aspects of ultrasound-guided regional anaesthesia (UGRA) [2-8]. These articles described ultrasound-guided approaches to nerves, aspects of 'sonoanatomy' and compared various aspects of UGRA (e.g. onset time, efficacy, dosages), to other methods of nerve location.

Where are we now?

We are now at a stage when we can say that the evidence base for UGRA has been laid. Fig. 1 is an estimate of the numbers of papers produced concerning UGRA year-on-year since 1994. At the time I performed this search, there had been over 350 papers produced in 2011 alone. The production of articles has mirrored the huge worldwide clinical interest in UGRA, and the use of ultrasound is probably responsible for the renaissance we have seen in clinical regional anaesthesia. Few would now disagree that the technique is effective and when properly implemented and may well be the gold standard for of block placement, certainly in peripheral regional anaesthesia, if not in neuraxial blockade [9].

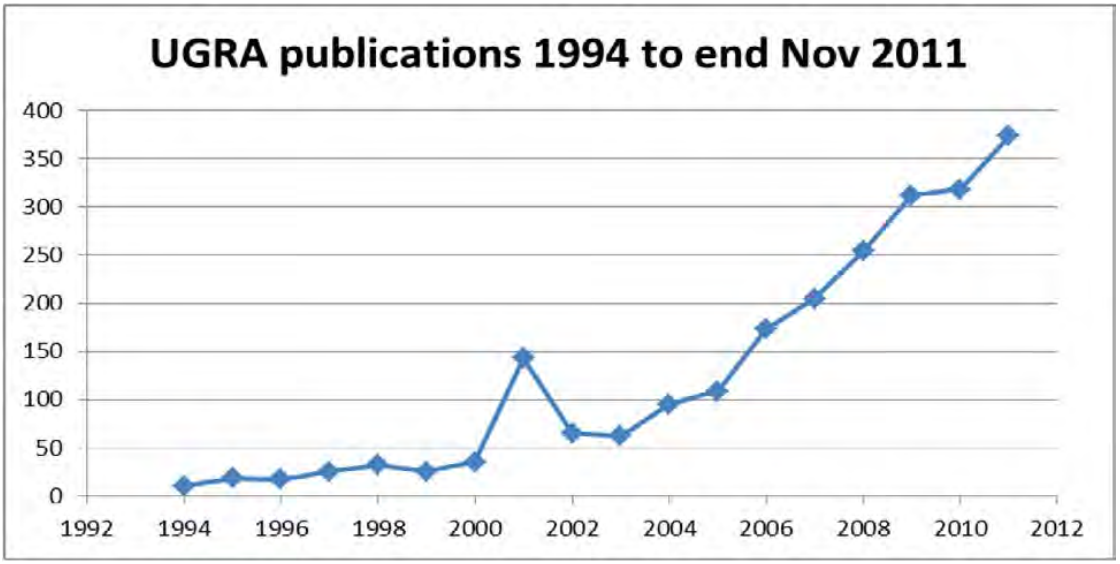

Figure 1: Google scholar hits produced (following filtering) from the keywords: 'ultrasound; local; regional; an$'.

What is 'publishable'?

Research seeks to answer questions and to provide new information about a subject. This is more problematic than one might think! In regional anaesthesia, describing a technique as 'new' is tricky, as most blocks are not new, but a modification of an already described technique [10]. However, the use of ultrasound has allowed us to 're-describe' many of the traditional nerve block approaches and also to examine a number of issues; for example the comparison of ultrasound-guidance with peripheral nerve stimulation (PNS) [11,12], and this has allowed us to understand some of the failings of PNS [13,14].

In addition to describing and characterising approaches to the various nerves using ultrasound, we have also seen a number of publications of complications starting to emerge and of course, these are extremely important for us to read and learn from during the introduction and refining of any new technique [15-17].

Anaesthesia: what do we want to read about?

Anaesthesia is the journal of the Association of Anaesthetists of Great Britain and Ireland. Its impact factor at the time of writing is 3.008. The Editorial Board of *Anaesthesia* wishes the journal to be first, a source of interesting, relevant and stimulating material for those practising in anaesthesia, intensive care, pain therapy and associated specialties, and second, a vehicle for debate and discussion related to these areas. The scope of material published in the journal and on its website reflects these aims, and the Editorial Team have them in mind when considering whether to accept or reject submitted work.

As editors reviewing material for publication in the journal *Anaesthesia*, we are no different (we hope) from our readers. In other words, we will favour articles if we believe they will be of interest to our readers. We welcome articles related to regional anaesthesia, and also like articles that we believe will create some useful debate [18-20]. Due to the vast numbers of papers already published around UGRA, there are probably various themes that will be successful. Harrop-Griffiths and Denny, with some justification, pointed out that 'there are no new blocks, just old anatomy'. However, ultrasound has allowed us to revisit many anatomical areas and refine our needle approaches in an attempt to reduce complications or improve local anaesthetic spread patterns. They went on to discuss a scientific approach to investigating a 'new block' (summarised below) [10].

A breakdown of the types of papers we might see submitted would be:

- 'New blocks', a standard pathway for describing a new approach:
- Original block description: the number of these is diminishing. But there are still approaches being described and I am sure a good number to come yet [21,22]. The first description should include the anatomic basis for the approach often with cadaver work or imaging in volunteers.
- Case series: these will usually follow an original description of an approach [23].
- Studies: proof of efficacy of a technique is best achieved by a randomised, controlled, blinded study, compared against the most similar previously described block [3].
- Post introduction surveillance, including case reports of complications [16,17].
- Original technology: advances have been rapid in ultrasound and future developments will include very high frequency ultrasound and improvements in three-dimensional imaging [24].

- Reviews: these articles are usually written by an author with proven experience in his or her subject. The article will summarise evidence in a certain topic in a digestible form for the reader and perhaps allow them to make judgments on how the topic should impact on their practice [25,26]. Anyone may choose to write a review and submit it for consideration, however, as these articles require a great deal of time and effort, it may be wise to contact the editor-in-chief and discuss plans for the article and suitability before embarking on writing the piece.
- Editorials: these articles are usually shorter than reviews, and are essentially expert opinion pieces, for example Picard's excellent article about neurological injury and regional anaesthesia [27]. An editorial may be linked to an article in the journal and so is often commissioned by invitation from the editor-in-chief following suggestion by the editors. An editorial may complement or raise issues with an article, the purpose being to clarify points and stimulate debate around a topic. A recent example in *Anaesthesia* was an article describing a potential new application for stellate ganglion blockade in acute pain [28]. We accompanied this with two editorials; one describing potential mechanisms for efficacy [29], and another cautioning against over-zealous enthusiasm for new techniques [30].
- Audits and surveys. *Anaesthesia* does receive many audits and surveys, but does not publish many (with some notable exceptions) [31]. In assessing suitability for publication, we consider how wide a sample has been examined and therefore the applicability to national practice of the audit or survey. The other issue, as with all articles, is the importance of the subject.

Importance: some articles will be published because the subject is considered important. In regional anaesthesia, an example of this might be the introduction of lipid rescue into clinical practice [32-34].

Themes: these often develop around a topic, for example education and learning in UGRA.

Letters and our correspondence website: each issue of *Anaesthesia* carries a correspondence column. We currently have two methods for submission; (i) the first is an original letter, which should be submitted through our editorial office in the same way as any other article, and (ii) a response to an already published article, which may only be posted on-line to our correspondence website at http://www.anaesthesiacorrespondence.com. We review all submitted letters, and 'lift' a proportion for publication in the main journal. Letters should be approximately 500 words in length with a single table or figure, and should aim to make a succinct point.

Why consider *Anaesthesia*, and what next?

When submitting a paper to any journal, please carefully read and follow the author guidelines (see web addresses below). The potential for acceptance of an article is not increased when it has obviously been formatted for another journal and will also require much work to render it easy to read and understand.

Good planning is important for any research paper, consider: the question or hypothesis, ethics approval, statistical design (sample size, power analysis, testing of data), study design (include a Consolidated Standards of Reporting Trials or 'CONSORT' diagram to make it clear), presentation of results (multiple comparisons, correctly formatted tables, do not 'over analyse' – ie keep it simple), the discussion should expand on the results and not simply repeat them and finally you should draw appropriate conclusions.

Ethics: *Anaesthesia* does require ethical approval for any study involving volunteers or patient

intervention. Surveys on patient data will need local Caldicott guardian (UK) or equivalent approval. For case reports, we require written, informed patient consent.

Writing style: we give specific author guidance on what we prefer, for example avoidance of the passive voice.

Fraud: all articles are scanned using software designed to discover plagiarism.

Review process: the editorial board prides itself on providing an efficient and personal service to authors. The turnaround time for review is kept to a minimum, and once a paper is accepted, the author will deal directly with one sub-editor to keep the sub-editing process as painless as possible while producing an improved final article.

Conclusions

Anaesthesia, like any journal, wants to receive and publish high quality, original work. Being a clinically based journal, regional anaesthesia and UGRA are excellent topics. Although many articles in UGRA have been published worldwide, we are still seeing many continuing to be produced. *Anaesthesia* prides itself on an efficient, personal review and editing process. We put much effort into improving the style and final appearance of our articles. We look forward to receiving your work!

Please visit our journal homepage for further information at
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Or our correspondence website at
www.anaesthesiacorrespondence.com

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The future of ultrasound

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In the past decade, a lot of progress has been made in ultrasound guided nerve blocks (USNB). It is still not an easy technique to master, but much easier than the landmark technique used prior to the institution of ultrasound. In the coming decade we will see continued advances in USNB and in the application of ultrasound to other closely related fields.

1. Three Dimensional Ultrasound

Three dimensional ultrasound is in regular use for obstetrics and echocardiography. The probes used for these applications operate at low frequency and low resolution [1]. The probes are large and the equipment is expensive. Because the probes operate at low frequencies, their main application in regional anaesthesia would be limited to nerve blocks that are deep in the body and in patients with extremely high body mass indices. At present this is the major weakness of two dimensional ultrasound guided block, i.e. obese patients are difficult to image as are the sciatic nerve and posterior lumbar plexus.

Once a three dimensional scan is made, the user can see the anatomy in any of three reconstructed planes simultaneously. In general, ultrasound images of nerves are best seen when the ultrasound beam is perpendicular to the surface of the nerve. Because it may be difficult to focus a beam which is perpendicular to a deep nerve, it may be useful to look at the image in several different planes. In addition, it will be easier to follow the path of the needle because the needle will not have to remain within the beam of a two dimensional probe.

2. Global Positioning Systems

One of the difficulties of ultrasound guided nerve block (USNB) is keeping the needle within the beam of the ultrasound probe. One company, Ultrasonix, has solved this problem by developing a needle which has a position sensor at its hub. This allows the user to have a virtual image of the needle and its tip superimposed on the ultrasound image. In this system, the user can always know where the tip of the needle is relative to his intended target. These needles will cost between US$20-50 per use. For deep structures, this technology may be worth the cost.

3. Echogenic Needles

It can be difficult to see the tip of the needle when ultrasound guided nerve block is done for deep structures and when the angle of the needle is nearly parallel to the path of the ultrasound beam. Most needle companies now make an echogenic needle which performs better at depth and steep angles. These needles are slightly more expensive than smooth needles but worth the cost for nerve block of deeper structures [1].

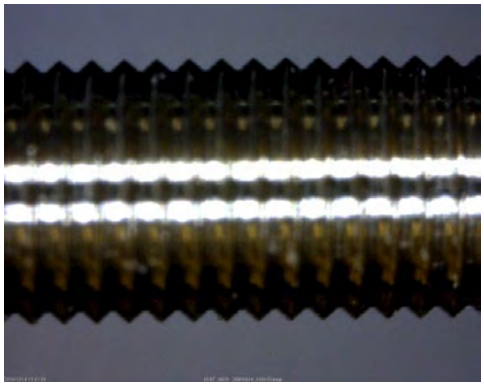


Figure 1. Echogenic needle

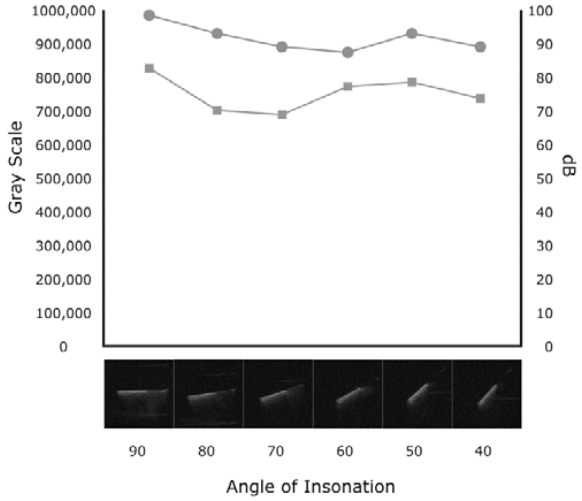


Figure 2. Comparison of virtual and real needle

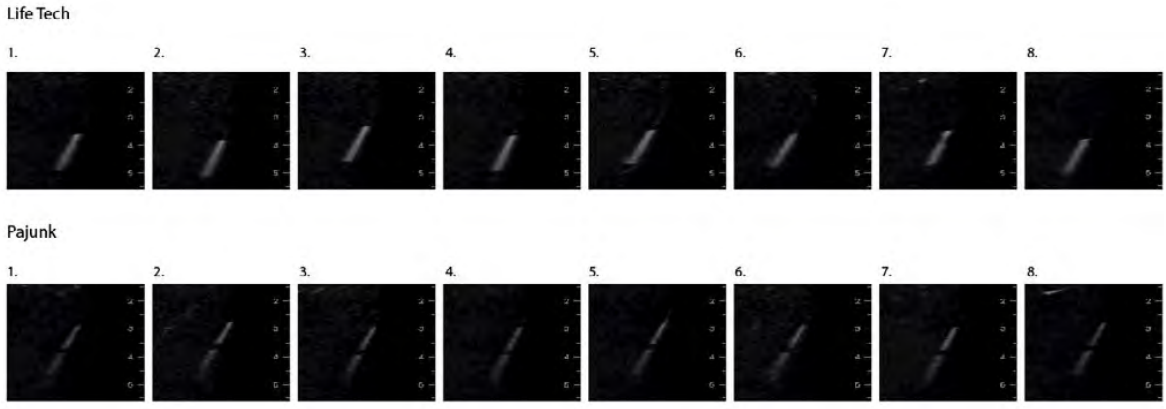


Figure 3. Comparison of real needles

4. Needle Guides

The ability of the user to simultaneously keep the needle aligned in the beam of a two dimensional ultrasound probe is difficult for all novice users. Needle guides are commercially available. These guides help to keep the needle aligned with beam for both in plane and out of plane use. These guides are most useful for deep blocks. The guides are expensive and not available for all probes. Lower cost and more universal application will be necessary before these guides are used daily.

Figure 4. Needle guide design

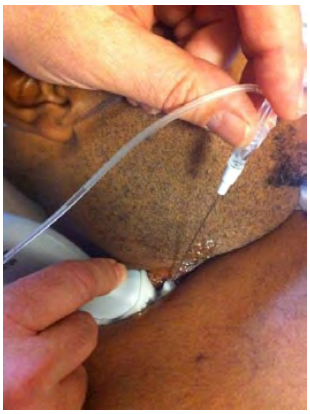


Figure 5. Needle guide

5. Machine Vision

Machine vision is a form of artificial intelligence wherein a computer is trained to recognize images. Common applications include finger prints, face recognition and the diagnoses of masses in breast lesions. The application of machine vision to ultrasound has been successful in patients with a body mass index of less 25. This will clearly be a useful tool to train novices. Application of the technology to obese patients is uncertain.

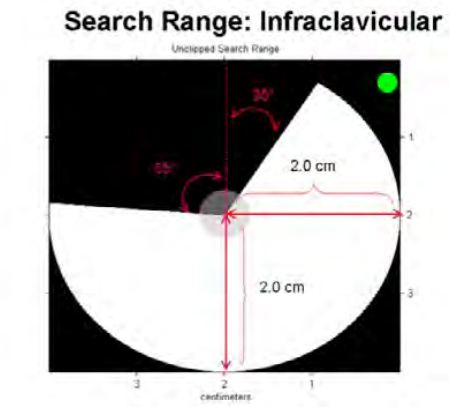


Figure 6. Range of infraclavicular nerves

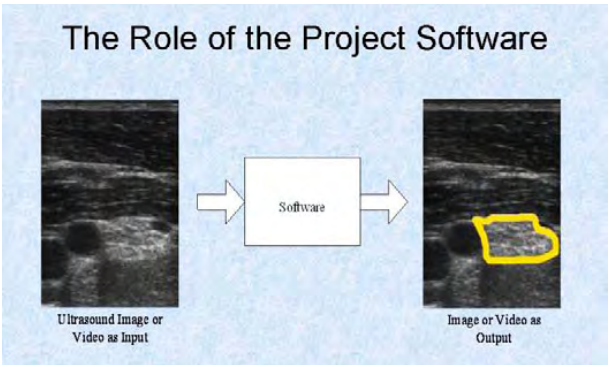
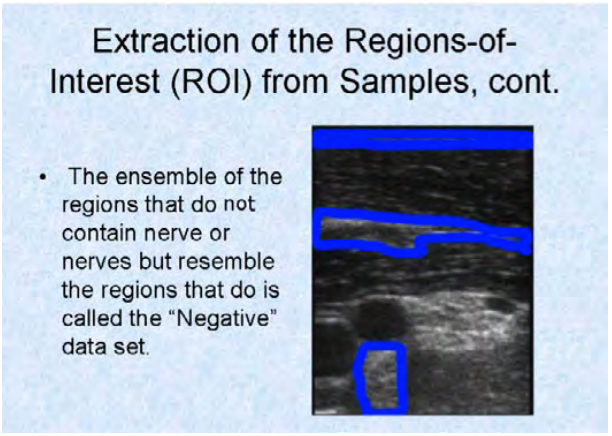


Figure 7. Role of machine vision

Figure 8. Identification of the negative data set



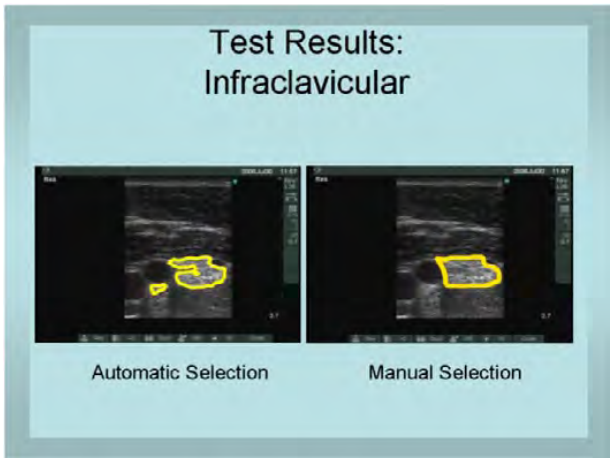


Figure 9. Machine vision and human identification of the plexus

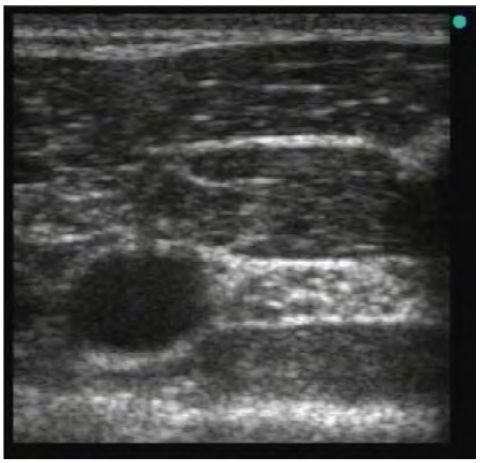


Figure 10. Ultrasound of the infraclavicular plexus

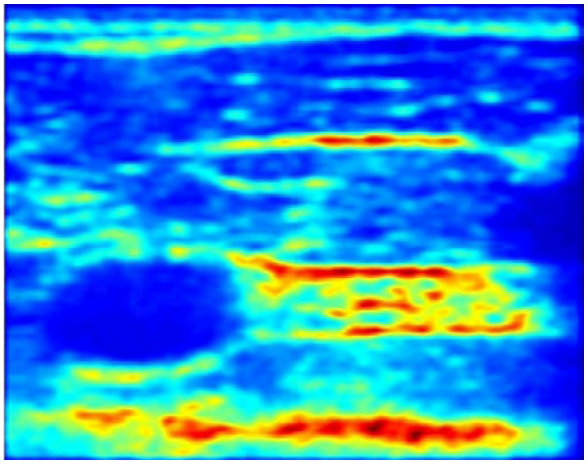


Figure 11. Texture energy plot of the infraclavicular plexus

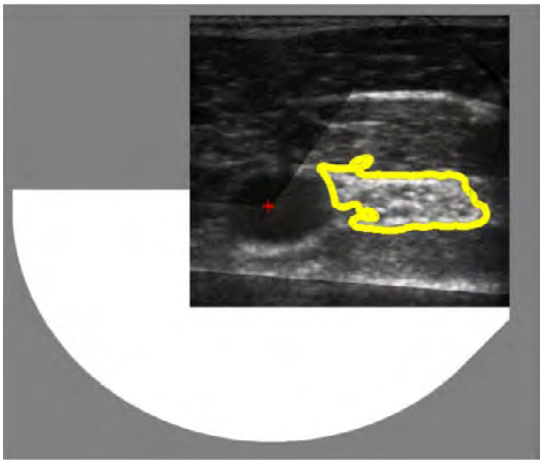


Figure 12. Machine vision identification of the infraclavicular plexus

6. Radiation Force Impulse Imaging and Sonoelastography

Radiation Force Impulse Imaging (RFII) measures the stiffness of tissue in the beam path. Nerves are stiffer than muscles, fat or blood. Thus, this technology can differentiate nerves from these other structures even when the nerves are not visible on standard ultrasound scans. The location of these nerves identified by RFII can be superimposed on a standard scan so that the user can use standard techniques to perform a nerve block. In principle, this technology could be very useful in obese patients and for deep blocks. Commercial machines are not available at this time. Sonoelastography is another technique which measures the stiffness of tissues. Its use in locating “invisible nerves” has not been proven. Its advantage over RFII is that commercial machines are already available if this technology proves useful.

7. Hand Held Devices

The original ultrasound devices were larger bulky machines which cost upwards of US$100,000. Hand held devices which now plug into smart phones are available for about US$10,000. These devices have low resolution. Nonetheless, devices which are the size of a probe and contain all of the associated hardware are in development. These platforms (probe with an integral screen) have an integral mirror which reflects the image directly back to the user are in development. These machines will likely cost about US$6,000 and will be useful for venous cannulation and superficial blocks.

8. Impedance Neurography and Microwave Tomography

Nerves give off electrical signals at rest just as the heart does. By placing an antenna on the skin, the location of nerves in the body can be imaged. The technology to do this (impedance neurography) has been proven and it is inexpensive. The main advantage of this technology is that it is useful in obese patients and for deep nerve blocks.

Broadband microwave tomography has been used to image the heart and other vital organs in the abdomen. A transmitter and receiving antenna is placed over the relevant part of the body. At present this technology is not commercially available. The technology is inexpensive, has low power requirements, and does not cook your body. It is unclear if this technology has the resolution to image nerves.

9. Pain Medicine and Rheumatology:

Ultrasound has rapidly made its way into the field of interventional pain medicine. It has been shown to be useful in cervical medial branch blocks, transforamenal blocks, neuraxial blocks, and visceral blocks of the stellate ganglion, coeliac, hypogastric and lumbar plexus's. It is also useful for refilling implanted opioid reservoirs, and in placing permanent stimulating catheters alongside of peripheral nerves. A few practitioners use ultrasound to assist with injection of the atlanto-occipital joint and for discography.

Ultrasound has also been found useful for injections of the shoulder, elbow, wrist and hand, hip and knee. This is mostly described in the rheumatology and pain literature.

Reference

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How small can we go? Applications of ultrasound in peripheral nerve blockade

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Introduction

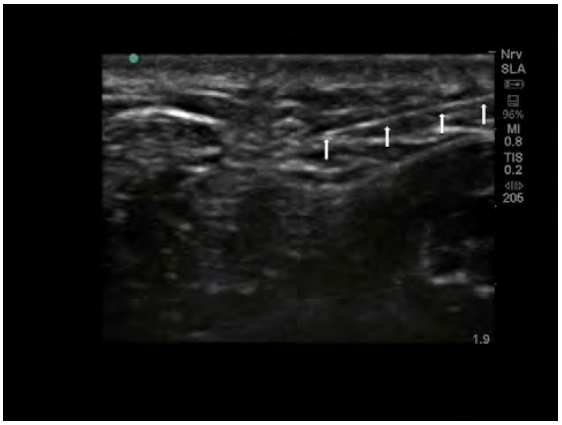
The purpose of this lecture is to consider how developments in handheld ultrasound technology have enabled us to visualise smaller structures, and consequently image some of the smaller peripheral nerves that may be useful to block during ultrasound-guided regional anaesthesia techniques.

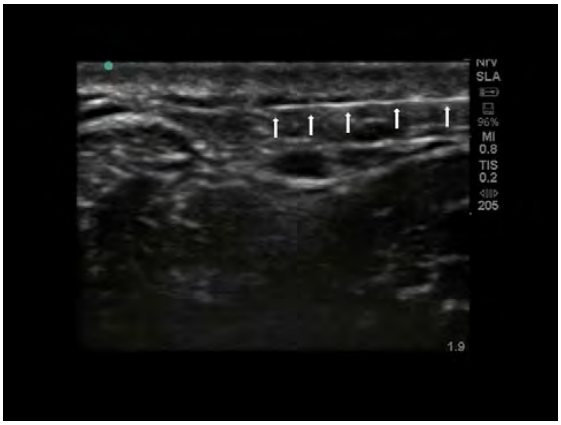
With the advent of so-called 'hand-held' ultrasound devices, came the opportunity for anaesthetists to purchase and use ultrasound to aid regional anaesthesia delivery in the theatre environment. This heralded a new 'golden age' of enthusiasm for these techniques, and we have seen huge interest both clinically and in research output. One of the issues with the early devices was the lower quality of the images, which meant that only larger nerves could be sought with confidence, and perhaps we were imagining a little more than imaging! However, a little like the computer industry, we have seen progressive leaps forward in imaging quality with each new generation of handheld device, and we now are able to resolve nerves of a few millimeters in diameter. This has allowed us to develop our understanding of 'sonoanatomy' to a much greater degree and become more accurate in our identification of nerve structures.

The visualisation of small nerves is not as critical as locating larger nerve roots and plexuses. However, it does allow us to 'fine tune' our techniques, either by being able to supplement a larger block, block an area more peripherally, try to avoid blocking specific nerves (e.g. phrenic during interscalene blockade) and also to perhaps use lower volumes of local anaesthetic.

Needle visibility

Early studies showed that needle visibility decays with insertion angle and needle diameter [1-3]. However, with improved imaging quality, it is now possible to perfectly visualise 27-G hypodermic needles during superficial regional anaesthesia techniques (Figs 1 & 2). I find these needles particularly useful for performing blocks of some of the smaller nerves, and routinely use them for multiple nerve blocks around the ankle in the conscious patient, in order to improve comfort and needle passage through superficial tissue. However, I would encourage great caution when using these sharp-tipped needles that were not designed for neural blockade and will therefore easily pierce nerve structures.





Figures 1 and 2. 27-G 40mm hypodermic needle (marked by white arrows) during an ankle (sural nerve) block.

Volume

There is good evidence that we can use low volumes of local anaesthetic when using ultrasound-guidance, and fairly good evidence that we can use lower volumes compared to other needle guidance techniques during peripheral nerve blockade [4-12]. This evidence is a reflection of the improved accuracy available to regional anaesthetists when using ultrasound-guidance. This provides real advantages in terms of safety (reduced volume) and efficacy (improved accuracy).

Nerve architecture

One of the fascinating developments in regional anaesthesia and the use of ultrasound imaging is the ability to examine nerve structures and improve our understanding of neural injury and block placement. It is clear that many traditionally placed blocks had an intraneural (at least sub-epineural) placement of the needle tip, but few of these injections resulted in nerve damage [13]. This information challenges traditional views that all intraneural injections are bad. Continuing improvements in picture quality and use of ultrasound will advance our understanding of these fundamental concepts.

Identification of 'smaller' nerves that I believe to be useful.

Ankle block

Blockade of the peripheral sensory nerves supplying the foot was traditionally performed as a landmark technique and one that this author often found frustrating, requiring high volumes of local anaesthetic to achieve reliable blockade. Following identification of the tibial nerve just proximal to the ankle, the sonoanatomy of the smaller peroneal nerves (Figs. 3 & 4) and the sural nerve can be learnt, which then allows the operator to perform ankle blocks with a fast onset and with a low volume (typically 10 ml per foot) and most importantly, a consistent result. Redborg et al found a greater success using ultrasound for sural nerve block when compared to the landmark technique [14]. I tend to perform sural nerve blocks just proximal to the lateral malleolus, which means that the calcaneal branch of the sural nerve is blocked with a resulting additional anaesthesia of the heel (Fig. 5). In a 6-year review of over 700 patients, Chin and colleagues found ultrasound improved their success rate over anatomic landmark-based ankle block for surgical anaesthesia during foot surgery, with trainees performing most blocks [15]. However, this group mainly blocked just the tibial nerve using ultrasound-guidance, and blocked the remainder using a landmark technique.

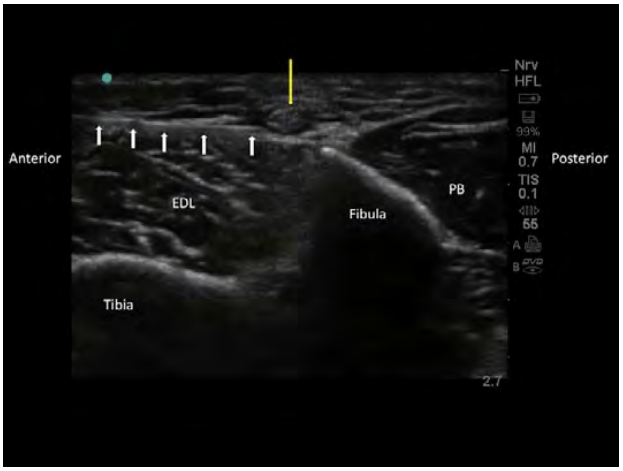
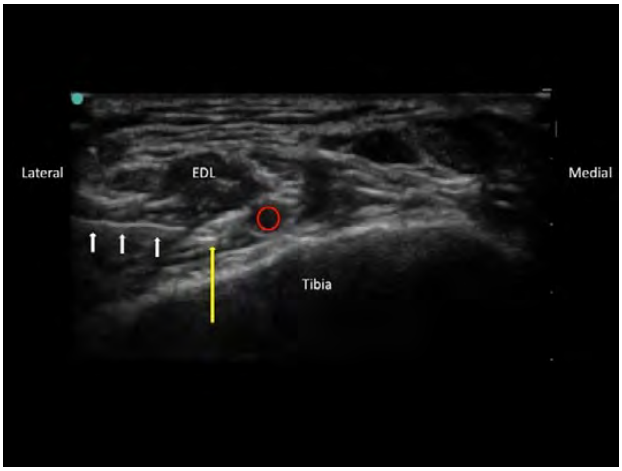


Figure 3. Superficial peroneal nerve; probe positioned transversely over lower half of calf. Find hyperechoic echo of fibula with overlying peroneus brevis muscle. On scanning in a proximal to distal direction, the nerve (yellow arrow) emerges from peroneus brevis muscle belly between peroneus brevis and extensor digitorum longus muscle and pierces the deep fascia overlying the muscles before splitting into terminal branches. A 27-G 40mm needle is shown next to the nerve (white arrows). EDL; extensor digitorum longus, PB; peroneus brevis.

Figure 4. Deep peroneal nerve; find dorsalis pedis artery (red circle) on foot and scan proximally to bring probe transversely over the tibia just proximal to ankle joint (this helps to delineate the nerve lying adjacent to the artery on the hyperechoic reflection of the tibia. A 27-G 40mm needle is shown next to the nerve (white arrows). EDL; extensor digitorum longus tendon.



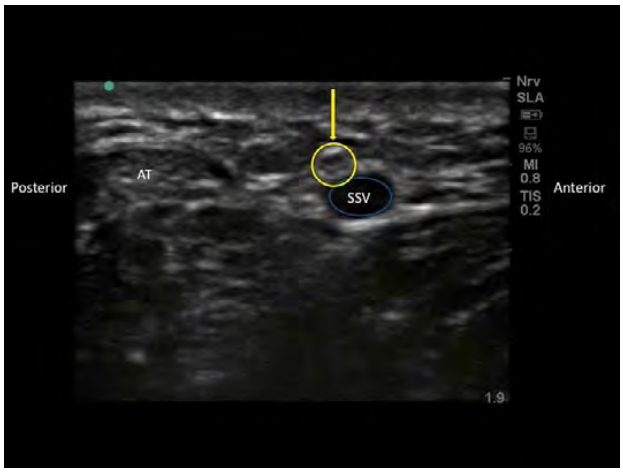


Figure 5. Sural nerve; with the probe in a transverse orientation, find the Achilles tendon posteriorly on the lower calf. Scan distally and observe the short saphenous vein (compressible) and accompanying sural nerve (yellow arrow/circle) rolling anteriorly and laterally off the tendon into an oval space between the Achilles tendon and peroneus brevis muscle. The scanning position is proximal to the lateral malleolus. AT; Achilles tendon, SSV; short saphenous vein.

Saphenous nerve block

The saphenous nerve is the terminal branch of the femoral nerve and can be reliably identified using ultrasound [16] and blocked in the sub-sartorial canal (Fig. 6) [17], or more distally in close relation to the saphenous vein in the lower leg [18]. Authors have attempted selective blockade of the infrapatellar branch of the saphenous nerve, but this volunteer study of infrapatellar nerve block also found frequent terminal saphenous nerve involvement following selective infrapatellar branch blockade [19]. The nerve may also be identified as it passes over two tendons; the first is the tendon of adductor magnus as the nerve leaves the adductor (Hunter's canal) before passing under sartorius and then, secondly, over gracilis tendon to pierce fascia lata and become a superficial structure. The saphenous branch of the descending geniculate artery is a useful accompanying landmark when trying to identify this small nerve.

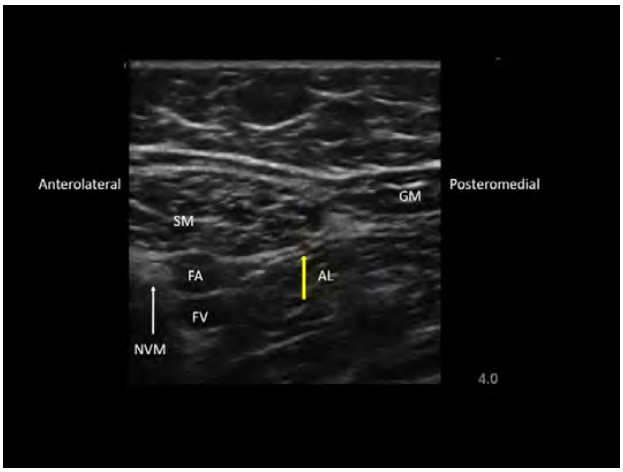
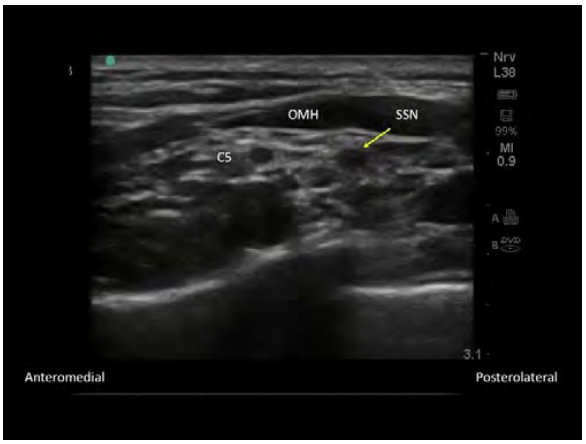
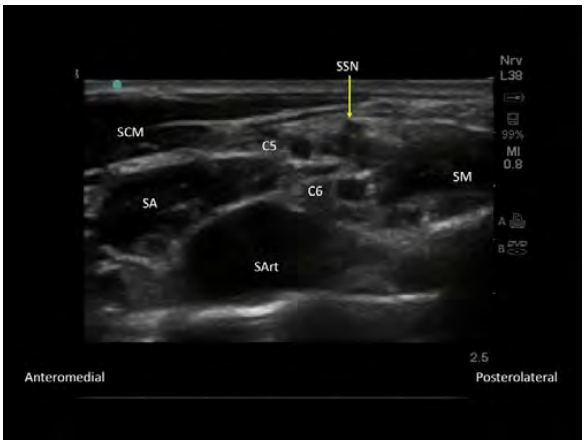


Figure 6. Saphenous nerve; scan over the medial aspect of the mid-thigh to locate the sartorius muscle with underlying femoral vessels. The saphenous nerve (yellow arrow) is seen passing away from the vessels under sartorius and then between sartorius and gracilis tendon to pierce fascia lata and become superficial. SM; sartorius muscle, GM; gracilis muscle, FA & FV; femoral artery & femoral vein, NVM; nerve to vastus medialis muscle.

Suprascapular nerve block

The suprascapular nerve provides extensive sensory innervation to the shoulder joint, and is commonly blocked to provide analgesia following shoulder surgery or during the treatment of chronic pain conditions [20]. The nerve is traditionally blocked using a landmark or ultrasound approach in the suprascapular fossa beneath supraspinatus muscle [21]. However, ultrasound imaging allows us to identify the origin of this nerve as it departs from the C5 nerve root and then passes underneath omohyoid muscle (Figs. 7 & 8), usually in close proximity to the suprascapular artery. It remains to be seen if blockade of the nerve at this more superficial position will have advantages over the deeper, more traditional approach.



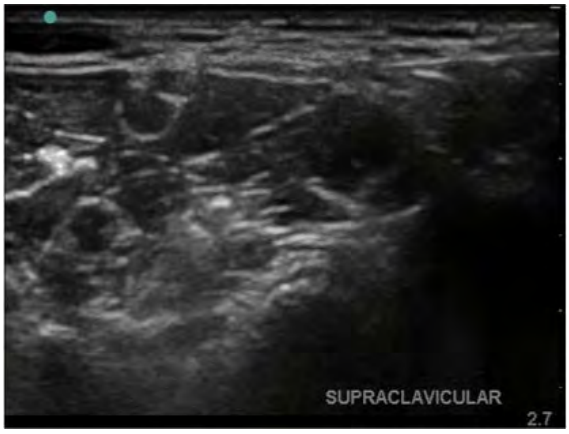


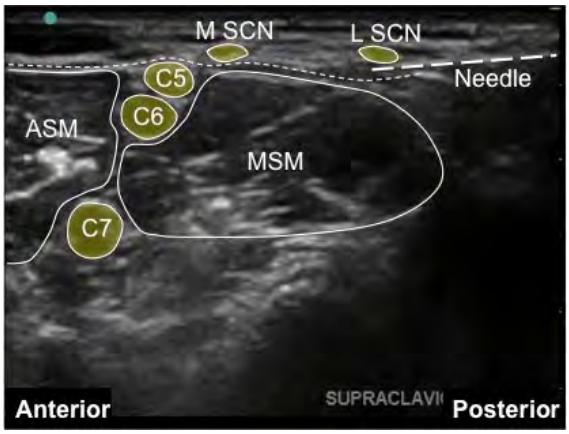
Figures 7 & 8. Suprascapular nerve origin; place the probe over the interscalene groove and locate C5 & 6 nerve roots between the scalene muscles. Scan inferiorly and observe the suprascapular nerve departing from C5 posteriorly (Fig. 7) and then continuing underneath omoyoid muscle as it travels posterolaterally (Fig. 8). The suprascapular artery is usually visible. The clavicle prevents the nerve being traced continuously into the supraspinatus fossa. SCM; sternocleidomastoid muscle, SA & SM; scalenus anterior & medius muscles, SArt; subclavian artery, SSN; suprascapular nerve, OMH; omohyoid muscle.

Supraclavicular nerve block

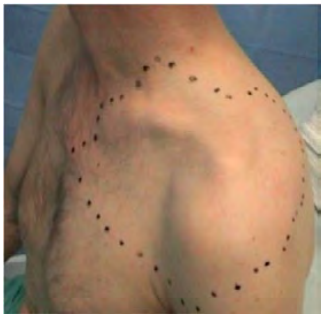
Traditionally interscalene brachial plexus blockade might have been achieved with 20-30 ml of local anaesthetic. The onset of ultrasound-guidance has allowed us to progressively reduce our volumes and still produce effective blockade of the upper roots of the brachial plexus [5]. This may reduce the side effects and complications associated with the block [4, 8, 10]. Using these smaller doses also probably reduces the incidence of blockade of the branches of the cervical plexus, and specifically for shoulder surgery, the supraclavicular nerve, which is the

most inferior branch of the cervical plexus and supplies sensation to the skin over the cape of the shoulder and also some sensation to the clavicle and acromioclavicular joint. Identification and selective blockade of the supraclavicular nerve using ultrasound is possible using small volumes of local anaesthetic [22]. Following identification of the nerve and its branches (Figs. 9 &10), I perform this block following interscalene blockade prior to arthroscopic shoulder procedures under regional anaesthesia. The block does not require a separate needle insertion and, in my experience, usually avoids blockade of the other more superior branches of the cervical plexus. Fig. 11 shows a typical distribution of sensory anaesthesia following specific supraclavicular nerve block.





Figures 9, 10 & 11. Supraclavicular nerve(s); Probe positioned transversely in an anteromedial/ posterolateral orientation over interscalene groove as for an interscalene nerve block. Scan caudally from level with C4 root and observe a small nerve passing superficially above the pre-vertebral fascia and posteriorly. The nerve typically branches as it becomes superficial. I usually perform this block after an interscalene block as I withdraw the interscalene block needle. The surface photograph (Fig. 11) shows the typical sensory distribution of anaesthesia. ASM & MSM; anterior & medial scalene muscles, M & L SCN; medial & lateral supraclavicular nerves.



Ilioinguinal/iliohypogastric nerves

The impact of ultrasound on blockade of these nerves was nicely described by Willsche and colleagues, who showed that ultrasound allows accurate location of these nerves (with reduced postoperative analgesic requirements) in children, a lower volume of local anaesthetic (compared to the landmark technique) and reduced placement of local anaesthetic outside of the correct neurovascular fascial plane (suggesting increased safety) [12, 23, 24]. In common with other smaller peripheral nerves, the ilioinguinal and iliohypogastric nerves are subject to considerable anatomical variation, and may therefore be difficult to locate, but the advantages of accurate location of the correct fascial plane still provides considerable advantages over the landmark approach (Fig. 12).

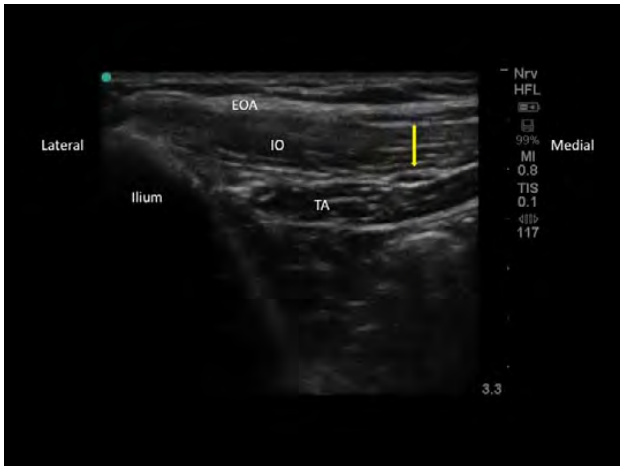


Figure 12. Ilioinguinal/iliohypogastric nerves; Scan transversely medially at the level of the anterior superior iliac spine (ASIS). Note that caudal to the ASIS, external oblique is aponeurotic. The neurovascular plane between internal oblique and transversus abdominis muscles is easily discernable. The nerves are seen as individual or double structures (yellow arrow). EOA; external oblique aponeurosis, IO; internal oblique muscle, TA; transversus abdominis muscle.

Nerves to avoid!

When discussing ultrasound approaches with trainees, I often discuss the advantages of scanning for the structures they wish to miss before concentrating on those they wish to target. Ultrasound allows us the luxury of locating nerves and vessels that may either lie in the pathway of the block needle or be implicated in block side effects. Careful placement of the needle and local anaesthetic may avoid damage to these nerves or reduce block side effects.

Examples of this include the superficial cervical plexus and the dorsal scapular nerve (passing posterolaterally through the substance of scalenus medius; Fig. 13). These nerves are under threat when performing an in-plane posterolateral to anteromedial interscalene approach. Careful pre-scanning can be used to avoid contacting these structures. I employ a low approach (below the cervical plexus) and try to visualise the dorsal scapular nerve directly, prior to needle insertion. One might argue that this ultrasound-guided approach creates this potential problem (by differing from the traditional Winnie approach), but I am more comfortable with the superficial nature of the needle trajectory across the neck, which is well away from the deeper, sensitive structures which have been transgressed with occasional devastating consequences following interscalene brachial plexus blockade [25-28]. The approach is also posterior to the phrenic nerve, which has also been damaged with approaches using nerve stimulator-guidance [29].

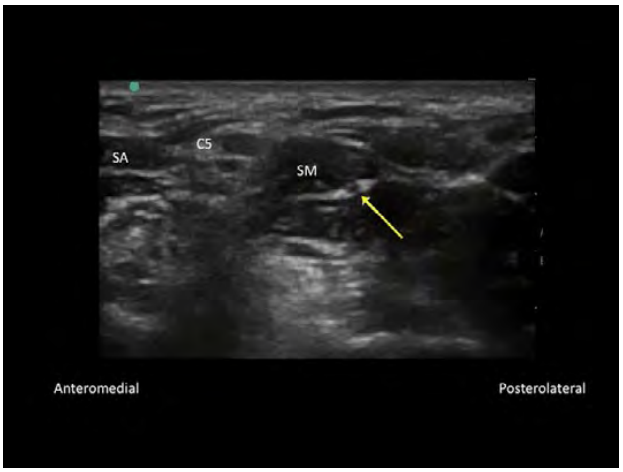


Figure 13. Dorsal scapula nerve; scan transversely over the interscalene groove, slight angulation of the probe will help to reveal the dorsal scapula nerve (yellow arrow) passing posteriorly and superficially through scalenus medius. SA & SM; scalenus anterior & medius muscles.

The phrenic nerve may be visualised as it passes over the anterior scalene muscle [30]. Several authors have examined both a lower (C7) position [8] and a low volume injection for interscalene block [10]. They both showed an encouraging reduction in the incidence of phrenic nerve paralysis following interscalene blockade. These studies were carried out in patients undergoing shoulder surgery under general anaesthesia, and it will be interesting to see if the results can be replicated in patients undergoing surgery under regional anaesthesia as a sole technique.

Several authors have also described ultrasound-guided blockade of the phrenic nerve for the treatment of intractable hiccups [31, 32].

Identification of 'smaller' nerves that I believe are of interest, but perhaps have less clinical impact for the theatre anaesthetist.

Cervical plexus block

The great auricular nerve is a (relatively) large branch of the cervical plexus, visible as it passes around the posterior mid-point of the sternocleidomastoid muscle to pass cranially and slightly obliquely and anteriorly on the surface of the muscle (Fig. 14). This nerve can be successfully blocked using ultrasound-guidance [33], but this is of limited relevance to the theatre anaesthetist. However, the point at which the nerve emerges is a useful landmark for placement of a superficial cervical plexus block.

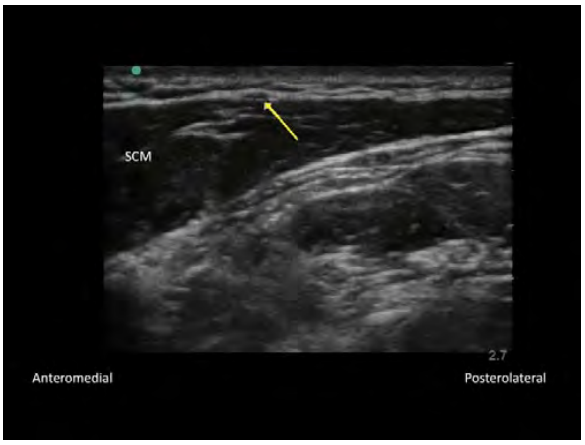


Figure 14. Great auricular nerve; scan transversely over sternocleidomastoid muscle in a caudad to cephalad direction and visualise the great auricular nerve travelling from posterior to anterior over the muscle as it emerges at the mid-point of the muscle and travels obliquely cephalad (arrow). SCM; sternocleido-mastoid muscle.

Lateral cutaneous nerve of thigh

The lateral cutaneous nerve of the thigh can be found [34, 35] and blocked using ultrasound [36] and is more reliably located than using a landmark approach [37]. The nerve can be located inferior to the anterior superior iliac spine as it passes under the inguinal ligament and over the proximal insertion of sartorius muscle to run between that muscle and tensor fascia lata muscle (Fig. 15). This block is of more clinical significance for chronic pain anaesthetists in the treatment of meralgia paresthetica [38]. In patients presenting for surgery, the nerve is usually blocked along with other techniques, such as fascia iliac blockade [39], or lumbar plexus blockade, but can be performed for patients undergoing hip surgery.

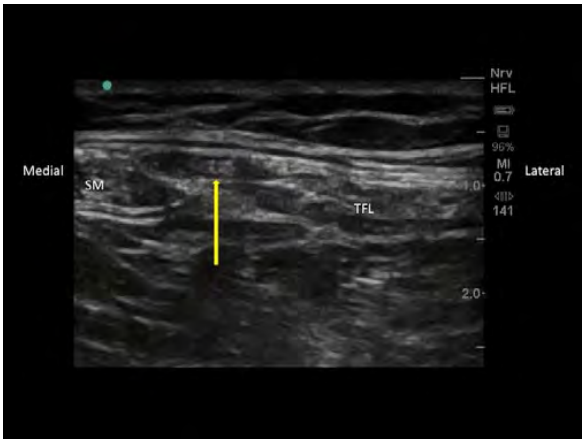


Figure 15. Lateral cutaneous nerve thigh; scan inferiorly from the anterior superior iliac spine with the probe in a transverse orientation. Observe the origin of sartorius muscle and the lateral cutaneous nerve of thigh passing superficially over the muscle to lie superficially between sartorius and the more lateral tensor fascia lata muscle (yellow arrow). SM; sartorius muscle, TFL; tensor fascia lata muscle.

Intercostobrachial nerve

The second intercostal nerve gives rise to the intercostobrachial nerve (ICBN). The nerve crosses the axilla to the medial side of the arm and supplies the skin of the upper half of the medial and posterior part of the arm (Figs. 16 - 18). The size of the nerve is variable and a second ICBN may arise from the lateral cutaneous branch of the third intercostal nerve.

The nerve can often be identified using ultrasound in the axilla, as it passes posterior to the plexus over the conjoint tendon of latissimus dorsi and teres major muscles, and can be blocked with a small volume of local anaesthetic. This block probably has limited value as a sole technique; I do not routinely perform it for tourniquet coverage, but consider it for surgery of the elbow or upper arm.

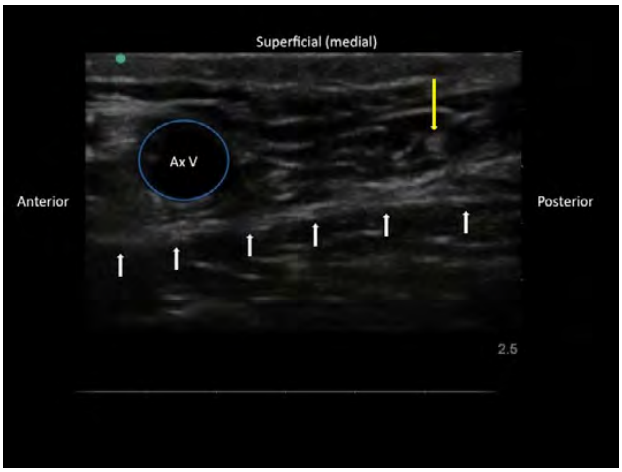
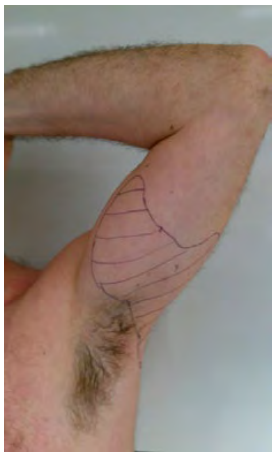
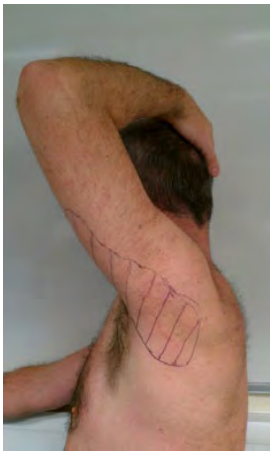


Figure 16. Intercostobrachial nerve; the probe is moved slightly posterior to the axillary vessels to reveal intercostobrachial nerve (yellow arrow) as it passes over the conjoint tendon of latissimus dorsi and teres major tendon (white arrows). Ax V; axillary vein.





Figures 17 & 18 are surface photographs showing typical sensory loss following the block.

Cutaneous nerves of the forearm

The medial cutaneous nerve of the forearm often divides to lie on either side of the basilic vein just proximal to the elbow (Fig. 19). The lateral cutaneous nerve of the forearm is the terminal branch of the musculocutaneous nerve which passes obliquely from the axilla between the biceps brachii and brachialis muscles to emerge just lateral to the biceps tendon and in close relation to the cephalic vein (Fig. 20). The posterior cutaneous nerve can be seen branching from the radial nerve when scanning on the lateral border of the upper arm, as it leaves the spiral groove of the humerus.

Although these nerves are identifiable, I do not routinely block them as a sole technique, as I usually require tourniquet coverage for hand surgery that is best served by a more proximal brachial plexus block. However, longer acting local anaesthetic can be placed around these nerves to provide post-operative pain relief.

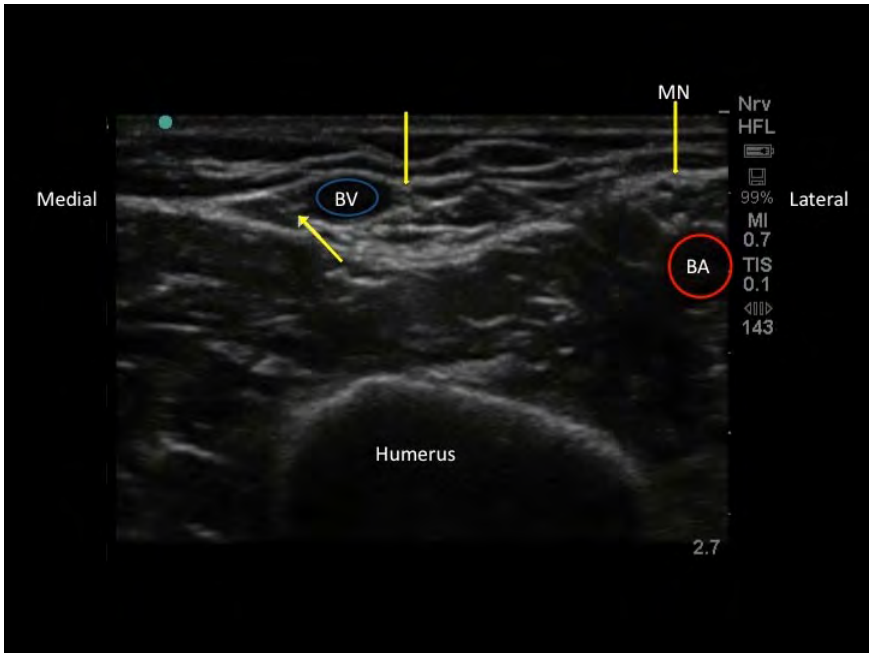
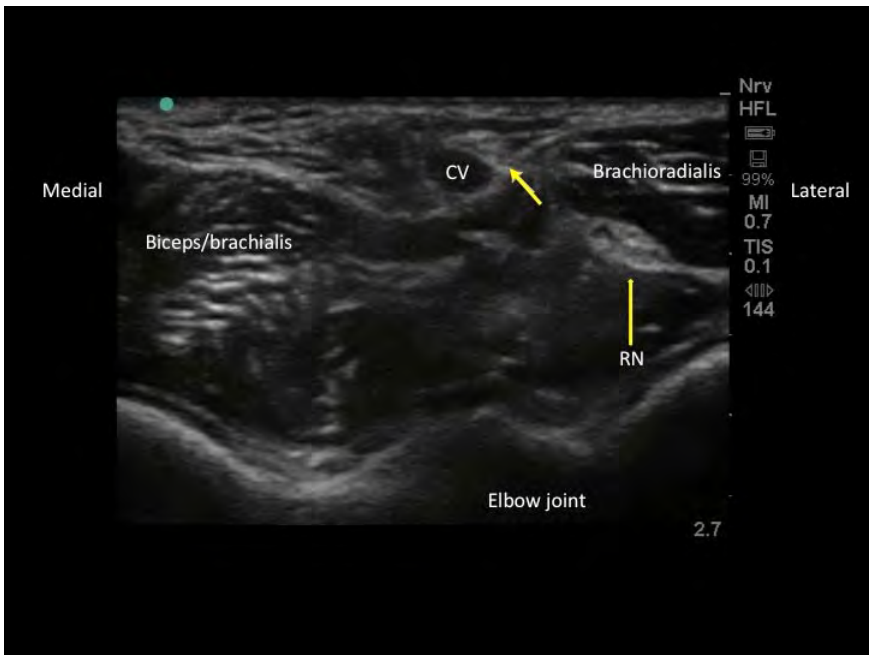


Figure 19. Medial cutaneous nerve forearm; probe positioned on inner aspect of upper arm just proximal to elbow. The basilic vein is seen medial to brachial artery and its accompanying median nerve. The medial cutaneous nerve is often seen as two branches lying either side of the basilic vein (two yellow arrows). BA; brachial artery, BV; basilic vein, MN; median nerve.

Figure 20. Lateral cutaneous nerve of the forearm; probe positioned transversely at level of elbow joint. Nerve emerges from between biceps tendon and brachialis muscle to join the cephalic vein (yellow arrow). RN; radial nerve.



Chronic pain

Clearly there are a number of advantages to the use of ultrasound imaging for the treatment of chronic pain conditions, and the accurate targeting and blockade of smaller peripheral nerves using ultrasound may help with diagnosis and treatment [40].

Conclusions

I have summarised a number of smaller nerves that we are able to visualise and block using ultrasound. The ability to visualise these nerves has given us the ability to fine-tune our blocks and also to understand and perhaps avoid some of the complications that may occur during their performance. Improvements in handheld ultrasound technology have made the blockade of these nerves possible in the theatre environment. I believe identification of these nerves and delineation of neural architecture will be made easier by further advances, including increases in ultrasound frequency and improvements in image processing, producing further improvements in picture resolution and quality.

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Sonography and regional anaesthesia of the spine and lumbar plexus

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Introduction

The use of ultrasonography for regional anaesthetic interventions of the spine and lumbar plexus is a relatively new technique. Part of the reason for the lag in widespread adoption may be technical: in contrast to superficial nerve and plexus blocks, the spinal canal and paravertebral areas are surrounded by or adjacent to a complex bony column that can render visualisation of target structures difficult, especially for an inexperienced sonographer. Despite this, there is a growing interest in using bedside ultrasonography to aid in spinal and paravertebral anaesthesia, especially for patients that are likely to be challenging.

Ultrasound Guided Neuraxial Procedures

Brief Overview of Sonoanatomy and Scanning Technique

For practical purposes, the spinal column can be imaged in two primary planes. The paramedian oblique orientation (**Figure 1**) is useful for gaining a window to the dura, ligamentum flavum and spinal canal via the intervertebral foramina (**Figure 2**), and determining the spinal level. The midline transverse orientation (**Figure 3**) is useful for determining the true midline (**Figure 4**), the midline depth to the ligamentum flavum and posterior dura (also known together as the posterior complex) (**Figure 5**), and for establishing the presence of any rotational defects. For both of these, it is critical to establish an acoustic window through non-bony structures in order to visualise the relevant structures such as the posterior complex and the spinal canal. In the transverse orientation, this often requires subtle cephalo-caudad translation of the transducer with or without a slight cephalad tilt in order to avoid the beam impacting the spinous processes. In the thoracic region, it is very difficult to obtain a useful view in the transverse orientation because of the steep, overlapping orientation of the spinous processes; however, it is still quite easy to visualise the dura and spinal canal via the paramedian oblique view in the thoracic region.

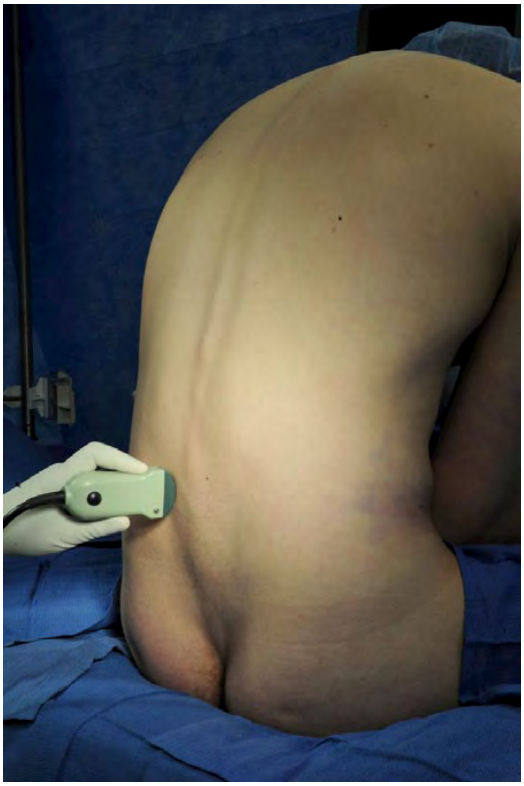


Figure 1. Parasagittal transducer orientation for imaging of the lumbar spine.

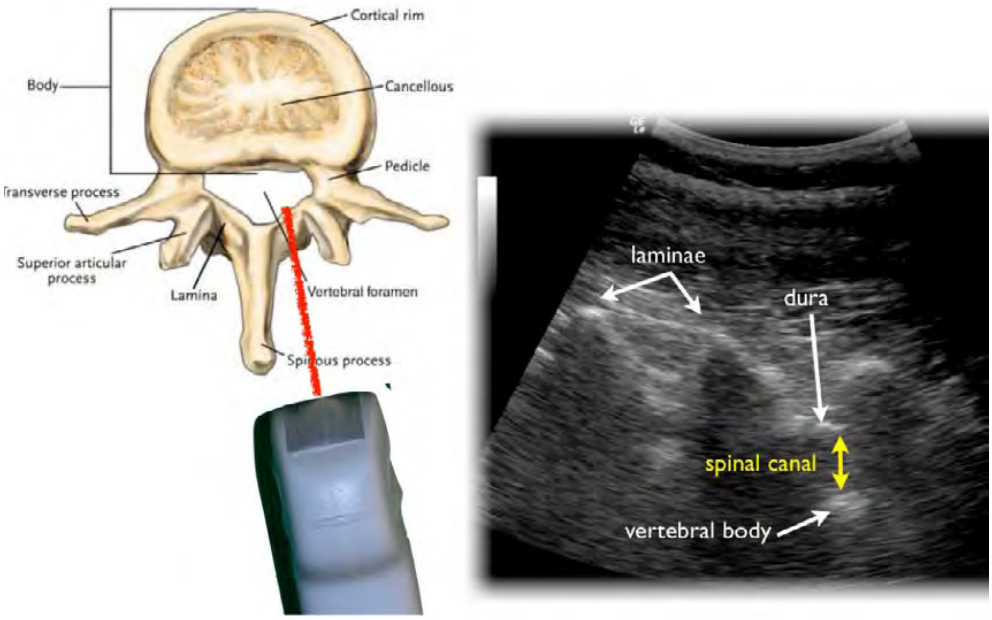


Figure. 2. Acoustic window obtained via parasagittal orientation and sonoanatomy.

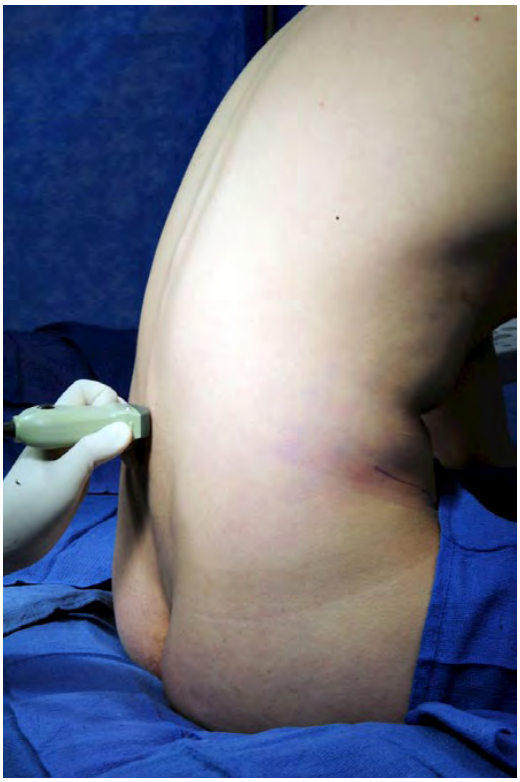


Figure 3. Midline transverse transducer orientation for imaging of the lumbar spine.

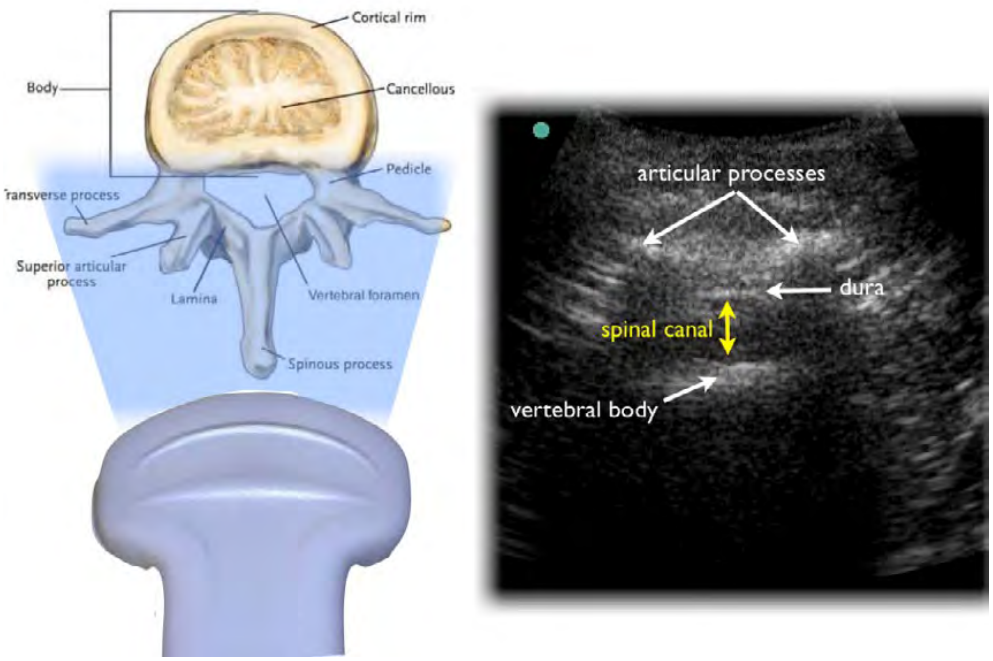


Figure 4. Sonoanatomy obtained via a transverse midline orientation. Note that transducer must be positioned in between two adjacent spinous processes in order to observe the dura.

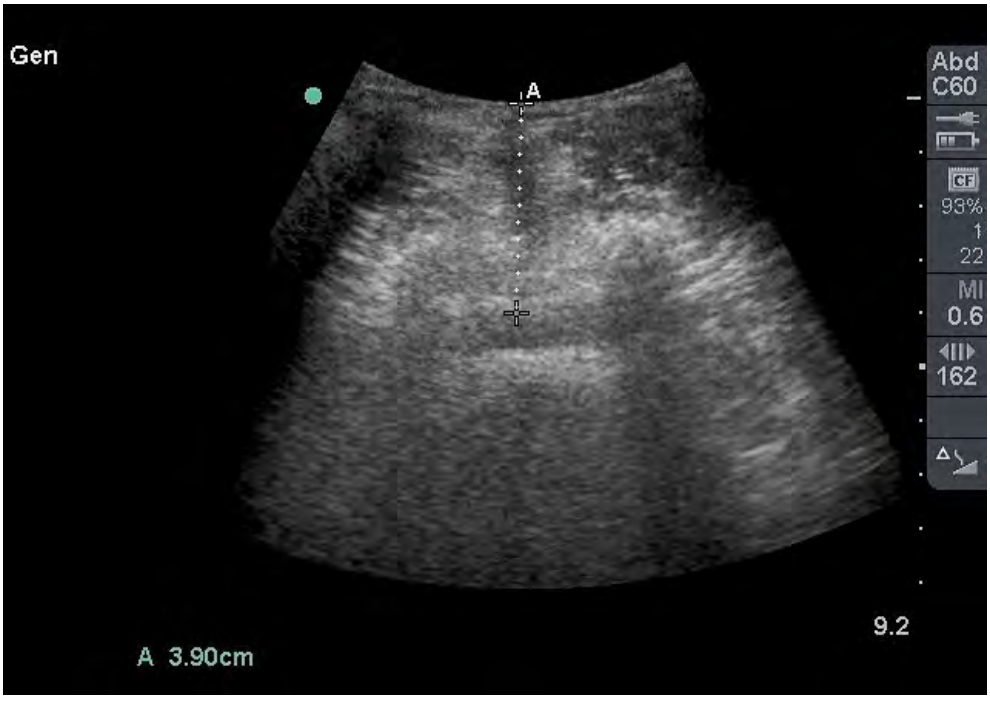


Figure 5. Transverse scan of the lumbar spine showing electronic calliper measurement of depth from skin surface to posterior complex (dura and ligamentum flavum).

There are two ways in which ultrasonography can be utilised with respect to neuraxial blocks. The first is as a pre-procedure scanning modality, in order to characterise the anatomy prior to a traditional “blind” technique. At present this remains the most popular use of the technology for the neuraxial indication. The other, more challenging use is to facilitate real-time guidance of needles into the spinal space. Each is addressed below.

Pre-Procedural Scanning

One of the fundamental ways in which ultrasonography has been suggested to benefit

clinicians is in the identification of landmarks relating to vertebral level, midline, as well as depth to the dura/ligamentum flavum. Estimation of the vertebral level by palpation of the iliac crests has been shown to be unreliable when compared to radiographs or MRI [1-3], but these methods are impractical for most clinical anaesthetists. In contrast, ultrasound-guided identification of the L3-4 interspace was correct in 76% of cases when MRI was used for control in a study of 17 patients [4] Likewise, in a study of 50 non-pregnant patients ultrasound improved identification of intervertebral level compared with palpation (71% vs. 30%) using lumbar x-rays as the standard [5]. In two recently published studies investigators scanned the lumbar spines of a total of 220 post-partum women who had received labour epidurals and compared the vertebral level of the skin puncture scar with that recorded in the anaesthetic record [6,7]. The sonographic level corresponded with the clinical level in only 36.4-55% of cases, and in some cases levels were off by 3 spaces.

Accurate knowledge of the depth from the skin to the ligamentum flavum may aid in preventing inadvertent dural puncture. The available evidence suggests that ultrasonography is reliable in identifying this distance in both the lumbar and cervical spine [8-10]. In a recent prospective, descriptive study of 50 patients undergoing spinal anaesthesia for lower limb total joint arthroplasty, Chin et al. demonstrated that the ultrasound-measured depth to the intrathecal space correlated well with the actual needle insertion depth, and overestimated the depth by just 2.1±5.4 mm [11]. Even in obese parturients with body mass indices (BMI) of 33-86 kg/m2, the estimated depth to the epidural space using ultrasound and the actual depth were similar (6.6 ±1.0 cm vs 6.3 ±0.8 cm, p=0.002) [12].

Pre-procedural scanning may also be useful when a difficult spine (e.g. scoliosis, instrumentation) is encountered. One case report of successful spinal anaesthesia following pre-procedural scanning in a patient with lumbar spinal hardware illustrates this point [13]. The authors initially encountered resistance while using a 25 gauge pencil-point needle, but based on their acquired knowledge from the ultrasound scan, determined that the cause of resistance was scar tissue and not bone or metal. The needle was exchanged for a 22 gauge cutting needle and successful dural puncture resulted.

Real-Time Ultrasound-Guidance

Earlier studies have tended to focus on the ultrasound-guided facilitation of traditional “landmark” or “feel” techniques. In contrast, several more recent investigations have looked into the feasibility of using ultrasound to guide the needle in real time to the epidural or intrathecal space, much like peripheral nerve blocks are conducted.

Grau et al. randomised 30 parturients scheduled for elective caesarean section to receive combined spinal-epidural (CSE) anaesthesia via standard loss of resistance (LOR) technique, ultrasound-assisted (i.e. pre-procedural scan) or with real-time ultrasound guidance using two operators [14]. No difference was found in efficacy, but there were a reduced number of attempts in both ultrasound groups.

Karmakar et al. described a series of 15 patients who received a paramedian CSE using real-time in-plane ultrasound guidance [15]. In contrast to the previous report, this technique was performed using a single operator, by employing a spring-loaded syringe that released its contents upon entry of the needle tip into the epidural space, thereby eliminating the need for a second set of hands. These authors also noted clear anterior displacement of the posterior dura upon injection of saline in approximately half of the subjects.

A prospective study of 19 parturients for elective caesarean section used real-time ultrasound guidance to perform CSE with the aid of a needle guide and projected needle trajectory line that allowed the investigator to line up the needle path with the acoustic window into the spinal

canal [16]. Once the needle was advanced to within 10 mm of the ligamentum flavum, a LOR syringe was attached and the needle advanced further until the epidural space was confirmed. Identification of the epidural space was achieved in 18 of 19 subjects.

Ultrasound-Guided Lumbar Plexus Block

While very useful for anaesthesia and analgesia of the thigh and knee, the posterior lumbar plexus block (LPB) has traditionally been considered an advanced block, only to be attempted after proficiency with other regional anaesthetic techniques has been achieved. This is primarily due to the nature of its location in the body. Packaged within the psoas muscle in the retroperitoneal compartment and close to the neuraxis, LPB is associated with a set of serious potential complications such as retroperitoneal or renal capsular haematoma, epidural or subarachnoid block, and systemic local anaesthetic toxicity [17]. In addition, traditional methods of locating the lumbar plexus can be either equivocal, such as loss-of-resistance, or may require multiple deep passes with a needle into a deep muscle belly before a motor response can be achieved, as is sometimes the case with nerve stimulation. Finally, one of the biggest challenges during lumbar plexus block is estimating the depth of plexus. A successful needle pass into the psoas muscle does not always guarantee a motor response during nerve stimulation; in these cases it is difficult to know when to stop advancing the needle before causing injury, and many clinicians are justifiably cautious about performing these blind techniques.

The use of ultrasound guidance for LPB allows the practitioner to visualise the important elements of paraspinal anatomy, including the projected needle path. As with all ultrasound-guided regional anaesthetic techniques, a thorough understanding of the anatomy is essential before attempting the block. The LPB is derived from the anterior rami of the spinal roots L1-L4, with a contribution from T12. After leaving the intervertebral foramina, the roots combine within the substance of the psoas muscle to form a plexus of nerves, from which emerge its six principal branches (Table 1).

Lumbar Plexus Branch	Roots	Sensory territory
Femoral nerve	L2,3,4	Anteromedial thigh & knee
Obturator nerve	L2,3,4	Distal medial thigh (variable)
Lateral femoral cutaneous nerve	L2,3	Lateral thigh
Iliohypogastric nerve	T12, L1	Suprapubic abdominal wall
Ilioinguinal nerve	L1	Inguinal region
Genitofemoral nerve	L1, L2	Femoral triangle, scrotum, labium majus

Table 1.0 Branches and sensory innervation of the lumbar plexus.

After passing around or through the psoas muscle, the branches exit the pelvis above or below the inguinal ligament, or via the obturator foramen.

Ultrasound guided LPB involves the identification of lumbar bony vertebral features and associated musculature, including erector spinae and psoas muscles. Other relevant sonoanatomical structures include the quadratus lumborum muscle, the kidney, the peritoneum, and the roots of the lumbar plexus itself.

Because of the depth of the structures in the lumbar plexus area, a curvilinear transducer (2-5 MHz) is best to adequately visualise the required elements. I prefer to perform these blocks with a nerve stimulator, to serve as an additional end-point for needle advancement. With the

patient in a lateral position (operative side up), the iliac crest and midline are palpated, and the transducer is applied in a transverse orientation immediately lateral to the spinal midline on the intercristal line (**Figure 6**).

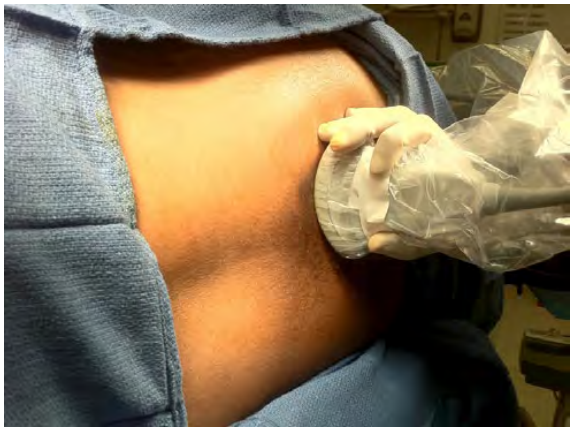


Figure 6. Transducer position for lumbar plexus block

The lamina and transverse process of L4 are identified along with the erector spinae and quadratus lumborum muscles. The transducer is then tilted slowly in a cephalad direction until an acoustic window is obtained between transverse processes that permits the visualisation of the psoas major muscle. The lumbar plexus is then identified as a hyperechoic oval opacity within the posterior aspect of the psoas muscle (**Figures 7A & B**).

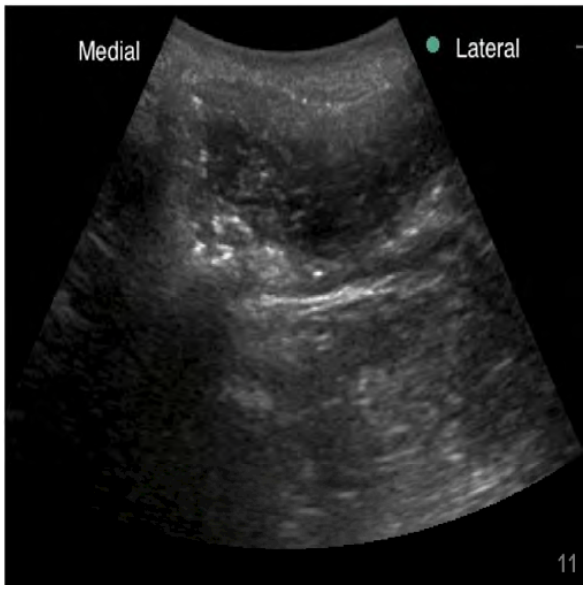
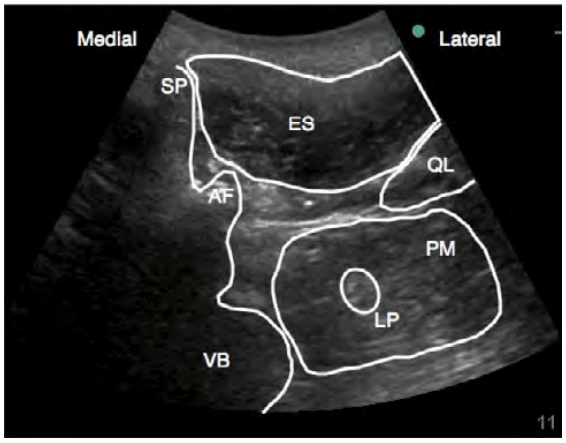


Figure 7A. Sonoanatomy of the lumbar paravertebral region (unlabelled)

Figure 7B. Sonoanatomy of the lumbar paravertebral region (labelled)



The skin immediately cephalad to the transducer is infiltrated with local anaesthetic and the needle inserted using an out-of-plane technique (**Figure 8**). The position of the needle can be inferred by tissue distortion and visualisation of the tip and/or shaft, while being directed into the psoas muscle towards the lumbar plexus.

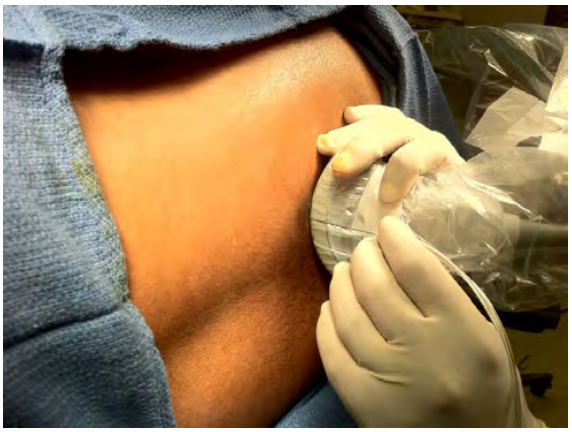


Figure 8. Needle insertion for ultrasound guided lumbar plexus block (out-of-plane)

The lumbar plexus is predictably located within 2 cm of the transverse processes [18]. Upon obtaining a quadriceps response, the current is decreased until twitches are observed between 0.2 mA and 0.5 mA. If a motor response persists at a current <0.2 mA, the needle should be withdrawn slightly until the current is only present within the above limits. After negative aspiration, 20-30 ml of local anaesthetic is then injected in 5 mL aliquots, with intermittent aspiration. We utilise injection pressure monitoring during LPB, as high (>20 psi) injection pressures have been associated with bilateral and high epidural spread [19]. Needle tip location at the initiation of injection can be confirmed with the use of colour Doppler in those instances where the spread in the psoas compartment is not obvious. In the case of contact with the transverse process, the needle is withdrawn to skin and angled 5-10 degrees cephalad. If a motor response is not elicited at the expected depth, or if the needle is seen deviating from the projected target trajectory, the needle should be withdrawn to skin and redirected appropriately.

Local anaesthetics should be selected based on the indication for the block (surgical anaesthesia versus postoperative pain) and the duration and intensity of anticipated pain. For example, knee arthroscopy involves a short, brief stimulus, but minimal postoperative pain, and the use of a medium-duration local anaesthetic such as lignocaine or mepivacaine 1.5% is appropriate. On the other hand, analgesia for hip fracture repair warrants the use of a longer acting drug: LPB with ropivacaine 0.2%, used in combination with a spinal anaesthetic, provides excellent postoperative pain control for this indication. In general, because of the large surface area and vascularity of the psoas compartment, clinicians should always attempt to use local anaesthetic volumes and concentrations that provide the least risk of systemic toxicity possible. A volume of 20 ml is often sufficient for postoperative analgesia; however, surgical anaesthesia often demands a slightly higher volume (e.g. 30 ml). Adrenaline (2.5-5 mcg/ml) is frequently added to our solutions in order to reduce the peak plasma concentration of local anaesthetic following injection.

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Development of the "Mitchell Needle"

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Regional anaesthesia is an innovative field. Stepwise innovation over the last 40 years has changed RA practice from localising peripheral nerves by needle induced paraesthesia, to nerve stimulation and more recently to ultrasound guidance. Ultrasound guided regional anaesthesia (USGRA) is also evolving with innovation in:

- anatomical site for the regional blockade
- volume and concentration of local anaesthetics used
- drugs added to the local anaesthetic mixture to increase the block quality and duration
- infusion techniques

At the same time, the image on ultrasound machines has steadily improved with advances in computer processing power, higher frequency probes, multibeam transducers and harmonic imaging.

In 2007, as an Anaesthetic Registrar working in ICU at Sir Charles Gairdner hospital in Perth, I was struggling with the technique of ultrasound guidance of subclavian CVL. This lead to my interest in needle visualisation – why was it that a metal needle only 2-3 cm under the ultrasound probe could be invisible? The answer lies in the law of reflection, which states that the angle of reflection equals the angle of incidence; needles inserted steeply reflect the ultrasound wave away from the transducer, hence remaining invisible. At this time there were over 20 published patents on methods to produce an echogenic needle but none were clinically successful.

My initial inspiration for improved needle visualisation came from light reflectors. The bicycle reflector is the simplest example. The specific shape of the reflector ensures that a car's driving lights are reflected back in the direction they come from, to ensure the driver of the car has optimal chance of seeing the bicycle.

Optimisation of this technology onto the tiny barrel of needle became a home shed pursuit over the following 6 months. Initial attempts with a punch and hammer were crude, frustrating and disappointing.

***Image 1:** Punch used to make indentation on the needle.*

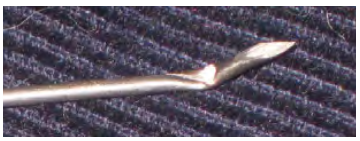

***Image 2:** initial attempt at modifying a needle.*

The breakthrough came with parts purchased from Bunning's and the development of a home made needle holder which allowed precise manipulation of the needle and a spring loaded hammer to give consistent but adjustable force on the punch.

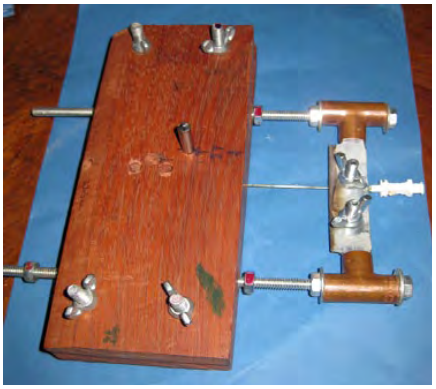

***Image 3**: Wooden needle holder.*

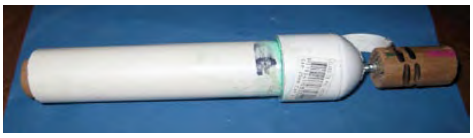

***Image 4**: Spring loaded hammer.*

These tools made it possible to make reproducible designs within a few hours. During the following months over 60 prototypes with differing shapes of indentation, depth, and patterns were tried. The ultrasonic characteristics of the prototypes were compared in homemade gelatin phantoms. Progressive improvements in design were rewarded with increasing echogenicity, and a confidence that “The Mitchell needle” was a significant advance likely to improve USGRA.

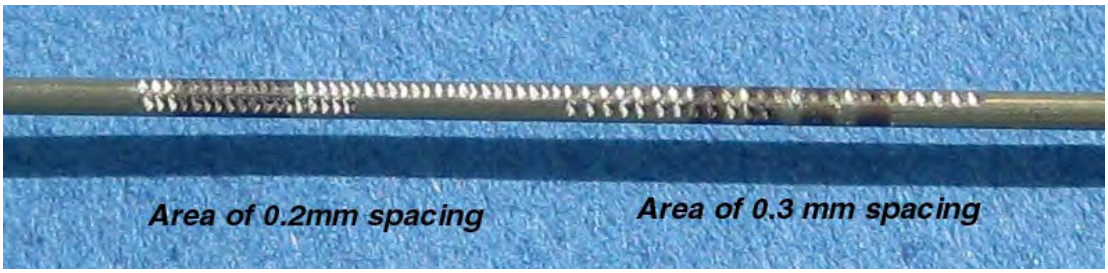

***Image 5**: Example of prototype 22G needle with several patterns of markings.*

Commercialisation of the idea was a slower and much more expensive process than making of the prototype. My fundamental problem was being ignorant of the process of commercialisation. After burning significant amounts of money with a large commercial law firm I was lucky to find a boutique company (Inner Maven) that helped guide me through the process.

A patent application requires expert drafting by a patent attorney and the process is technical and complicated. The initial steps of a Provisional Patent and later a Patent Co-operational Treaty (PCT) give the inventor a 30 month window to optimise their prototype and find a company or financial backer to take on the substantial costs of national based patents which, over the life of a patent, are currently worth about $250,000.

My initial hopes that Australia’s only medical needle manufacturer, Portland Surgical Products Pty Ltd, might be interested in producing “The Mitchell needle” were quashed when it was bought by a Western Australian company and immediately shut down.

Of the international manufacturers Pajunk proved to be the stand out company. Pajunk’s nanoline technology enabled the reflectors to be insulated without the bulky Teflon, which causes a loss of echogenicity. Additionally I was able to contact them via the Australian distributor Surimex. I negotiated directly with the heads of the family company which was a pleasant experience compared with the impersonal mechanisms of larger companies which require inventors to deal with web sites and sign “Disclosure Agreements” before any discussion can occur. Pajunk was able to fast track the idea, and the Sonoplex needle was being sold 30 months after I had my first ideas of improving needle echogenicity.

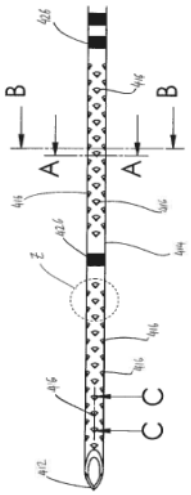

***Image 6**: Final Design of Sonoplex needle*

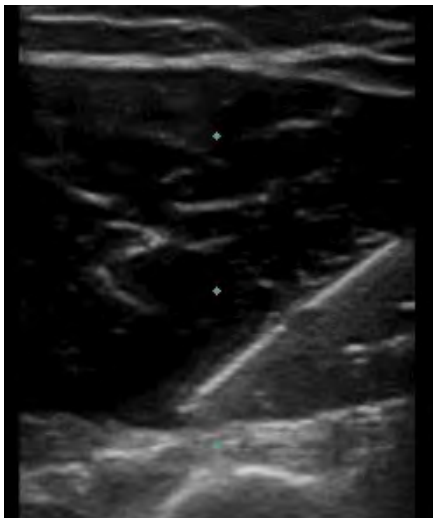

***Image 7**: Radial nerve block with Sonoplex needle*

The ”Mitchell needle” idea is now on the full range of Pajunk Regional anaesthesia needles, including the Sonoplex needles for single shot techniques and the SonoLong catheter set. The latest product in the range is the VascularSono needle: an echogenic vascular access needle designed particularly for the placement of central venous lines. The VascularSono needle has made ultrasound guided subclavian vein access easy, solving the problem that I had in ICU four years ago.

Pleasingly, published research comparing needles has demonstrated the superiority of the Sonoplex needle. The Sonoplex needle tip visibility has been shown to be “independent of the angle of insertion” [1] and “at steeper angles, the Sonoplex showed significantly higher confidence and visibility scores” [2]. This improved visibility reduces “needle to nerve time” in a blue phantom [3]. More importantly, in clinical performance “the Sonoplex needles scored significantly higher for tip visibility compared to the Stimuplex Ultra and standard Stimuplex, during both needle advancement ($p < 0.01$ for both) and injection ($p < 0.01$ for both)” [4].

The Sonoplex needle should allow further innovation in USGRA. The needle visibility with steep insertion angles allows insertion next to the probe making it easier to enter the “in plane” view of the ultrasound transducer and also minimises the distance the needle needs to travel through the tissue. Deeper blocks like the infraclavicular nerve block become easier. Most importantly seeing the needle tip is easier which allows more accurate needle tip placement that should improve patient safety.

The final challenge for the “Mitchell needle” is convincing hospitals and anaesthetists to change. Hopefully the mounting evidence of its benefits will aid in the adoption of this new innovation.

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What do we know about intra-neural injections

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Definitions:

1) Medical Knowledge: Substantial literature on human patients from randomised outcome studies.
2) Medical Opinion or Expert Opinion: An individual physician or panel of physicians who have made recommendations based on their own anecdotal experience, case reports, retrospective studies in humans or observations and studies in animals.
3) Medical Beliefs: Ideas or practices based on folk lore, theology, or opinions and studies which are unsubstantiated.
4) Peripheral Nerve: A structure containing bundles of axons. Between the axons is endoneurium. Surrounding each bundle of axons is a membrane called the perineurium. The collection of axons contained within the perineurium is called a fascicle. The space between the fascicles is occupied by fat, blood vessels and connective tissue. Surrounding the fascicles, and connective tissue, fat and blood vessels, is a membrane called the epineurium.
5) Brachial Plexus: A collection of nerves surrounded first by the deep cervical fascia and then varying layers of mesoneurium.
6) Sciatic nerve: The combination of the peroneal and tibial nerves. The membrane surrounding the tibial nerve is called the epineurium as is the membrane surrounding the peroneal nerve. The membrane surrounding both the peroneal and tibial nerves is called mesoneurium.
7) Intrafasicular Injection. Injection deep to the dura in a nerve root or deep to the perineurium in a nerve.
8) Parafasicular Injections: Injections which are placed between the epineurium and perineurium.
9) Extraneural Injections: Injections outside the epineurium of single nerves. Injections outside of the deep cervical fascia or between the deep cervical fascia and the epineurium in the brachial plexus. Injections between the mesoneurium and epineurium separating the trunks in the brachial plexus. Injections outside of the sciatic nerve or between the peroneal and tibial nerves in the sciatic nerve.
10) Subepineurial Injections: It is not possible with ultrasound alone to determine whether an injection deep to the epineurium lies inside or outside the perineurium. In this setting, an injection deep to the epineurium is simply defined as a subepineurial injection.

Architecture of the Nerve:

The nerve root is formed from the anterior and posterior rami of the spinal cord. It then emerges from the lateral recess of the spine. In this region, the nerve consists of one or two fascicles which contain the sensory and motor axons. The fascicles are covered by dura. At

this proximal level, the architecture of the nerve root is similar to the spinal cord. That is, most of the nerve deep to the dura is occupied by axons.

At the level of the trunk, the nerve structure is covered by epineurium. Deep to the epineurium are multiple fascicles covered with perineurium. Between the fascicles are fat, connective tissue and blood vessels. At this level, less than 50% of the nerve is occupied by axons. More distally, the proportion of non-neural tissue in the nerve increases (Figure 1).

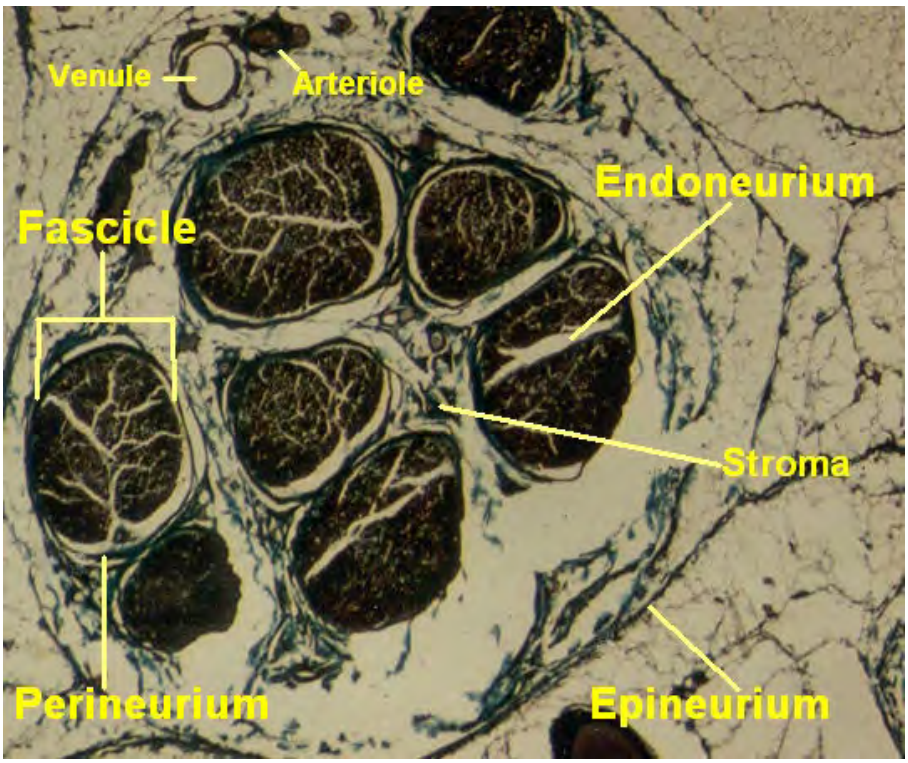

Figure 1: Light microscopy of the median nerve

Animal Studies:

Chan studied intraneural dye injections in 28 pigs [1]. Most of the injections were parafasicular with simulation thresholds ranging from 0.12 to 1.8 mA. There were two intrafasicular injections. There was no evidence of axonal disruption. Hadzic injected lignocaine into 14 sciatic nerves in 7 dogs [2]. When high pressures were recorded, there were permanent neurological injuries at 7 days in 4 injections. Whitlock injected ropivacaine extraneurally, parafasicularly and intrafasicularly in rats. All three sites showed some axonal destruction in all three groups [3]. Iohom injected ropivacaine into the sciatic nerves of 42 rats. There were no clinical deficits in any of the rats (67 days) [4]. Lupu injected the median nerve of 10 pigs with lignocaine. There were no clinical deficits in these animals (7 days) [5]. Selander inserted cutting and noncutting needles into rabbit sciatic nerves. He concluded that short bevel needles were less likely to injure nerves [6]. Kapur injected lignocaine into the sciatic nerves of 15 dogs. He founded that high injection pressures resulted in injury to the nerve [7].

Human Studies Using Ultrasound:

Bigeleisen injected 72 peripheral nerves in 22 human patients with a mixture of bupivacaine and lignocaine (figure 2). There were no injuries in these patients [8]. In another study, Bigeleisen injected the brachial plexus in 39 patients with bupivacaine and lignocaine. Stimulation thresholds inside the nerve ranged from 0.0 mA to 1.8 mA. There were no injuries in these patients [9]. Robards injected 20 sciatic nerves in patients with an unknown local

anaesthetic. Intraneural stimulation thresholds ranged from 0.2 mA to 1.8 mA. There were no neurological complications [10]. Sala-Blanch injected mepivacaine into the sciatic nerve of 17 patients and followed them clinically and with electrophysiological studies. There were no clinical injuries or electrophysiological abnormalities [11]. Dufour found that lignocaine injected into and around the median nerve in humans had a higher success rate than lignocaine injected around the nerve. This was not significant. There were no injuries in these patients [12]. Bigeleisen found that injection of ropivacaine or bupivacaine into the musculocutaneous or median nerve of 20 patients resulted in faster onset but equivalent success rates (100%) compared to injection around the nerve [8]. Bigeleisen reviewed the results of 5732 intraneural injections in the brachial plexus with ropivacaine using blunt needles. There was one injury lasting three weeks. Bigeleisen reviewed the injection of lignocaine and bupivacaine into the brachial plexus of 20 humans using a cutting needle. There were four long term injuries. Orebaugh studied the injection of local injection directly into the nerve root of 9 human cadavers at C5. All injections resulted in high pressures and destruction of the nerve root [14].

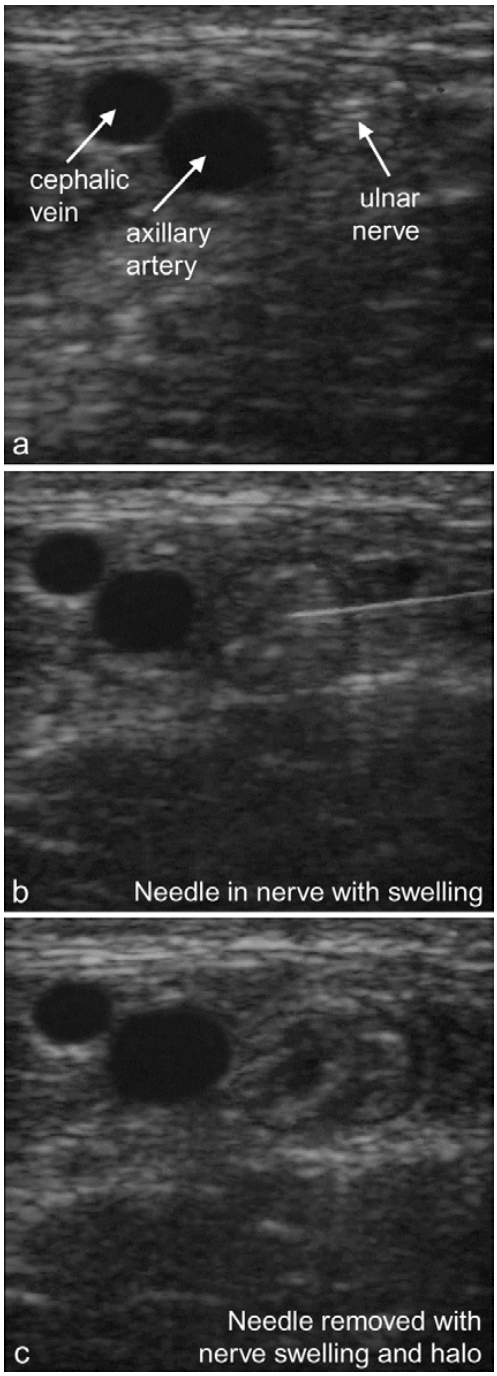

Figure 2: Intraneural injection in the axilla

What Do We Know?

1) There are no randomised studies in animals that suggest that intraneural injections are safe or dangerous. There are observational studies (expert opinion) in animals and humans that suggest that sharp needles should be avoided and that intraneural injections accompanied by high pressures are more likely to cause injury than intraneural injections accompanied by low pressures.

2) There are no randomised studies in humans that show subepineurial injections are safe or dangerous. There are small observational studies in humans (expert opinion) that suggest that subepineurial injections have a low risk. Subepineurial injections of the median and musculocutaneous nerve were not more efficacious than injections outside these nerves. Injections deep to the mesoneurium of the sciatic nerve were more efficacious than injections outside the nerve (expert opinion).

Summary:

Electro-stimulation studies imply that subepineurial injections occur about 30% of the time (expert opinion). Retrospective ultrasound studies suggest that subepineurial injections occur about 20% of the time (expert opinion). We know very little about the safety and efficacy of intraneural injections.

It is my own belief after observing and performing more than 5000 subepineurial injections that they are more efficacious than injections outside the nerve and that the risk of injury is very low when blunt needles are used at low injections pressures. This efficacy is most apparent when the nerve to be blocked is large (sciatic nerve) or when a plexus block is performed. The injury rate with this technique is so low that we cannot devise a study to measure it.

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Intraneural injection during regional anaesthesia - Con

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Introduction

Intraneural injection of local anaesthetics during regional anaesthesia is considered an avoidable risk factor for nerve injury. In animal experiments, intraneural injection of local anaesthetics, particularly intrafascicular injection, may result in axonal damage [1-3]. To understand the potential implications of intraneural injection an understanding of the anatomy, histology and pathophysiology of mechanical injury to peripheral nerves is required. A recent review of intraneural injection and peripheral nerve injury by Gadsden includes an excellent description of the anatomy, histology and histopathology of peripheral nerves as it relates to peripheral nerve blockade [4].

Histology of Peripheral Nerves

The structure of a peripheral nerve is represented schematically in Figure 1. The epineurium is a loose collection of collagen fibres, is easily permeable and carries the nutritive vessels of larger nerves. The epineurium is located around and between the nerve fascicles containing axons and also surrounds the entire peripheral nerve. Fascicles are surrounded by the perineurium, a tough squamous epithelial sheath, which acts as a semipermeable barrier to local anaesthetics. The perineurium is considered the protective layer and its disruption may be a key mechanism in nerve injury from needles. Nerve fibres (axons) are supported within the perineurium by a delicate connective tissue matrix called the endoneurium. Endoneurium provides a protective environment for the delicate axons and contains capillaries that arise from epineurial vessels.

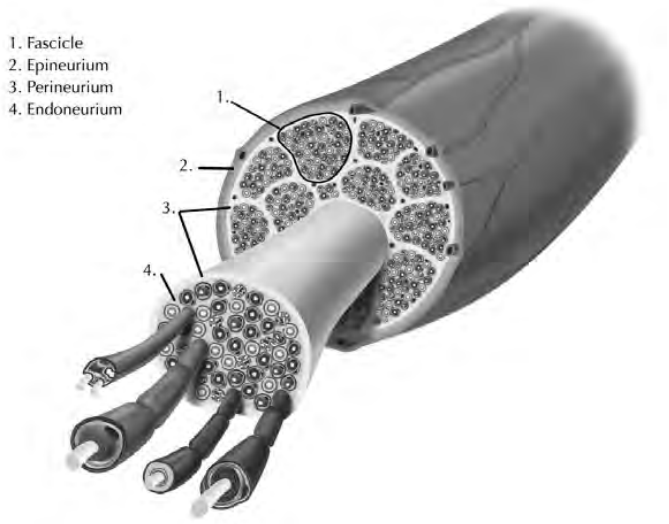

Figure 1. Schematic diagram of peripheral nerve demonstrating fascicles, perineurium, epineurium and endoneurium. With permission from Mary K. Bryson.

The ratio of connective tissue to neural elements in peripheral nerves increases from proximal to distal (that is the cross-sectional fascicle-epineurium ratio decreases the more distal the nerve). The fascicles may compose as little as 25% of the cross-section of distal nerves [5] and in contrast the interscalene region has a very low connective tissue to neural ratio [6].

Intraneural injection may occur within the loose compliant epineurial tissue that surrounds the fascicles or within the neural elements proper (the fascicles) with the fascicles having a much lower compliance. Therefore intraneural injection can be classified as intrafascicular or subepineural (subepineurial is the term used by some authors). Intrafascicular injection is associated with high injection pressures and neural injury [2,3,7]. In the interscalene region, the boundaries of the epineurium are not distinct and may be adherent to the scalene fascia and in one cadaver study subepineural injection occurred in 5 out of 10 specimens [6].

Pathophysiology of peripheral nerve injury and intraneural injection

The pathophysiology of peripheral nerve injury is complex with different classification schemes. The response to injury is unique involving a dynamic process of degeneration and reinnervation. Basic injury types in clinical practice include stretch, laceration and compression. Mechanical deformation and ischaemia are thought to be key events leading to degenerative changes following pneumatic compression [8,9]. Intrafascicular injection results in: disruption of the perineurium, loss of the protective environment provided for by the endoneurium and an initial rapid increase in intrafascicular pressure that may exceed the capillary pressure resulting in ischaemia and inflammation [1-4,7]. Intrafascicular injection of ropivacaine is associated marked histological abnormalities comprising: inflammatory responses, haematoma, myelin damage, oedema of the perineurium and axonal destruction with Wallerian degeneration [2].

A. Mechanical factors

Mechanical disruption of perineurial sheath results in leakage of endoneurial contents however, this is not consistent [3]. Needle trauma and other mechanical insults are associated with a variety of cellular changes (e.g. increase in neuropeptide production and dorsal horn activity) [3,8]. Needle tip characteristics influence the likelihood of fascicular penetration. Long bevel needles are more likely to puncture the fascicle compared with short-bevel needles and a recent cadaveric sciatic nerve study supports this (out of 134 fascicles in contact with the needle tracks, only 4 were damaged, all belonging to the sharp needle group) [10]. Blunt and larger needles are less likely to enter a fascicle, but if they do, they appear to cause more damage compared to a sharp needle. The severity of nerve injury after needle nerve perforation relates to the diameter of the needle [11]. However, no such difference exists for regional inflammation [12].

B. Toxicity of Local Anaesthetics and Additives

All local anaesthetics are potentially neurotoxic [2]. Exposure of peripheral nerves to local anesthetics may result in axonal damage, particularly if the solution is injected intrafascicularly, if the concentration is high, and if duration of exposure is prolonged [3]. Needle penetration of a nerve may result in minimal lasting damage unless this is combined with local anaesthetic administration within the nerve fascicle [3].

C. Blood supply to nerves

Peripheral nerves have a dual blood supply of intrinsic vessels in the endoneurium and an extrinsic plexus of vessels in the epineurial space (feeding vessels run longitudinally along the nerve) that cross the perineurium to anastomose with the intrinsic circulation. The epineurial

circulation is a critical component of the overall circulation to the nerve, because its removal reduces nerve blood supply by 50%. Neural blood flow (NBF) is in the range of 9-15 ml/100gm/min (comparable to cerebral white matter) [13]. Local anaesthetics and adjuncts have the potential to reduce neural blood flow, and trauma from intraneural injection may compromise blood flow further [13,14].

Imaging techniques

Ultrasound imaging does not have sufficient axial resolution to distinguish intrafascicular from extrafascicular injection. Intraneural injection is typically demonstrated with swelling during ultrasound imaging. This is consistently observed in animal studies where intraneural injection (nerve swelling) correlates with extra-fascicular histological changes, [15,16] but not functional changes [17].

Clinical studies using ultrasound

Intraneural injection may occur and not cause overt clinical signs of nerve injury [18-20]. However, the opposite has been noted with an intraneural injection during ultrasound-guided interscalene block resulting in a severe but transitory neurologic deficit [21]. Our attitudes to intraneural injection have been challenged by Bigeleisen, [19] who conducted a study where nerve puncture and apparent intraneural injection during ultrasound-guided axillary block did not invariably result in neurologic injury. In this study, 50 patients were recruited, however 22/50 patients were excluded because of preoperative abnormalities in their qualitative sensory or motor examinations. In the first instance there were a very small number of patients recruited to this study (50). But a large proportion of patients were excluded and therefore the question should be asked – do the results apply to my clinical practice or just to healthy patients? We don't know what the incidence of nerve injury is in the cohort of patients who have abnormalities of their qualitative sensory or motor testing. The study included a small sample of healthy patients receiving axillary brachial plexus block that arguably, is one of the safest in terms of nerve injury. A larger study by Liu [18], recruited 257 young, healthy patients having ultrasound-guided interscalene or supraclavicular block for shoulder surgery. The incidence of unintentional intraneural injection was 17% and there was no evidence of postoperative nerve injury. What is unknown from that study is the exact site of injection: intrafascicular, extrafascicular but subepineural? Regardless, both studies are underpowered to determine incidence of nerve injury due to intraneural injection defined by nerve swelling during ultrasound-guidance [18,19].

Clinical studies using nerve stimulation

There appears to be no consistent level of stimulating threshold that reliably indicates intraneural placement of a needle in a wide range of anatomical locations. At the supraclavicular location, a stimulation current of 0.2 mA or less appears reliable to detect intraneural placement of the needle. However, stimulation currents of more than 0.2 and no more than 0.5 mA (a range of threshold thought to be related to efficacy) could not rule out intraneural position in that study and patients with diabetes had higher thresholds [20]. During popliteal sciatic nerve block low-current stimulation was associated with a high frequency of intraneural needle placement. An injection in the intraneural space occurred in all patients who had motor-evoked response at current 0.2-0.4 mA. In addition, the absence of motor response to nerve stimulation during popliteal sciatic nerve block did not exclude intraneural needle placement [22].

Definition of intraneural injection

The clinical definition of intraneural injection varies from one anatomical site to another.

Orebaugh reasonably points out, that the exact location of the epineurium in the interscalene region may be ill-defined, and therefore injection within the epineurium may occur commonly in this location [6]. Related to this, the question has been raised as to whether penetration of the epineurium during supraclavicular block constitutes intraneural injection [23]. Similarly, subepineural injection was a common occurrence after nerve stimulator-guided sciatic nerve block in the popliteal fossa, yet it did not inevitably lead to neurological complications [24]. However further discussion and anatomical studies are required describing anatomy in terms of intraneural and subepineural injection at different sites. It should be acknowledged that detecting intraneural injection may be unreliable related to technology, operator and patient factors.

Summary and key points

Intraneural injection is controversial and is not standard practice.

The correlation between intraneural injection and neurological dysfunction remains unclear. Although intraneural injection may not cause nerve injury, the numbers of patients recruited to studies are inadequate to capture such an infrequent event as peripheral nerve injury.

The clinical studies conducted thus far, have been on small cohorts of healthy patients. The results do not apply to patients at higher risk of perioperative nerve injury.

Intraneural and subepineural injections have different implications at different anatomical locations.

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ultrasound guided peripheral nerve block; How low can you go?

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Introduction

Ultrasonography has brought vision and insight to the practice of peripheral nerve block. Ultrasonography has answered many questions such as: 'where is the nerve?'; 'where does the local anaesthetic (LA) go?'; and 'are there blood vessels close to the nerve?'. While ultrasonography has answered many questions, it has challenged us to ask many more. In particular, the two hottest interrelated topics in ultrasound-guided peripheral nerve block (USNB) are: optimal needle position prior to LA injection; and how much LA is necessary to facilitate successful peripheral nerve block.

This talk will focus on the assumption that extra-neural needle placement is the 'norm' and will review the available evidence on LA dose and USNB in upper limb regional anaesthesia. This talk will also focus primarily on the use of USNB for anaesthesia. It is likely that the LA dose requirements for anaesthesia and analgesia are somewhat different.

Considerations

It has been demonstrated that successful peripheral nerve block requires blockade of more than 70% of the transmembrane sodium channel population present on the target segment of a peripheral nerve [1]. The suggested length of a target segment of peripheral nerve equates to length of nerve occupied by three consecutive nodes of Ranvier [1]. Given that sodium channel density, sensitivity and subtype is determined by a myriad of genetic and environmental factors, it is likely that significant inter-individual variability exists as to the number of LA molecules required to achieve adequate impairment of impulse propagation along a peripheral nerve.

Injectate volume

Traditionally, it was accepted that as long as the block needle was in the same area as the target nerves, a sufficient volume of LA injectate would 'flood the fascial plane' and reach the desired target. By accepting the concept that injectate volume alone may compensate for technique limitations and inter-individual anatomical variation, LA dosing in peripheral nerve block evolved based upon the maximal allowable drug dose in the largest, convenient-to-administer volume (30-40ml). Large volume nerve block is akin to using a shotgun to shoot a mosquito. While the outcome may be successfully achieved, there will inevitably be collateral damage. As most peripheral nerves travel in close relation to large veins and arteries, both systemic absorption and unintentional occult intravascular injection of LA are possible with potentially catastrophic consequences (local anaesthetic systemic toxicity [LAST]) [2,3]. Local anaesthetic may also cause harm to surrounding structures such as skeletal muscle [4]. Therefore limitation of the LA dose and volume used in USNB is advisable.

Ultrasonography transforms the block needle into a precision instrument and facilitates the deposition of small volumes of LA adjacent to target nerves. The next question that arises is: what is the smallest volume of LA required to achieve successful nerve block? In answering this question, study methodologies have largely fallen into two categories:

1. Dixon and Massey dose finding studies (step up/step down);
    - O'Donnell and Iohom [5]: 1ml per nerve 2% lignocaine with 1:200,00 epinephrine in axillary brachial plexus block
    - Casati A et al. [6] $MEAV_{50}$ bupivacaine & ropivacaine at femoral nerve; 14 +/- 2 ml
2. The relationship between nerve surface area and volume required to provide circumferential local anaesthetic spread.
    - Eichenberger [7] Volume relative to surface area study, LA dose = 0.11ml/mm^2 Ulnar nerve in forearm, ED_{50} 1% mepivacaine = 0.7 ml
    - Harper et al [8] volume to 'surround axillary brachial plexus components; median 3.4 ml, ulnar 2.75 ml, radial 2.58 ml, musculocutaneous 2.3 ml

Injectate concentration

Although the volume of LA required to achieve successful nerve block may be an independent predictor of block success, it must be remembered that the number of LA molecules is also a consideration. Given the aforementioned requirement to have greater than 70% sodium channel blockade across a segment of peripheral nerve to achieve blockade of impulse propagation, it is likely that a 'critical number' of LA molecules is required. To date, too few studies have addressed the relationship between USNB, LA volume and LA concentration to make any definitive statements. Further work is required on this topic.

Nerve structure [9]

Are all peripheral nerves the same? The answer to this is obviously no. However they all share some common features. At the level of the brachial plexus nerve roots, the fascicular bundles are tightly packed into a somewhat non-compliant sheath. This sheath consists of epineurium, an extension of the dura mater and an investing layer of connective tissue (mesoneurium). Within the nerve the majority of the tissue is primary neural tissue with little intraneural connective tissue. Thus extraneural LA at the level of the nerve root must traverse multiple layers to gain access to the axonal sodium channel. Contrast this with the peripheral nerve at the level of the forearm, which is invested in a thin, loose and compliant epineurium. The intraneural contents form the minority of the contents of the nerve with fatty loose connective tissue the predominant content. As such extraneural LA at the peripheral nerve has fewer physical barriers to overcome en route to the axonal sodium channel.

Local anaesthetic diffusion into a peripheral nerve is governed by Fick's Law: diffusion is directly proportional to lipid solubility, concentration gradient, membrane permeability and available surface area. As the nerve surface area to neural content ratio varies significantly from nerve root to terminal branch, this is likely a further consideration in determining the true minimal effective LA dose.

Injectate placement

I will briefly mention the thorny topic of ideal LA injectate placement. Intuitively by

depositing LA close to the surface of a nerve, circumferential spread can be achieved with comparatively small doses of LA. In 21st century anaesthesia, the block needle is now a precision instrument which can be guided directly toward the peripheral nerve. Twenty first century technology has however inherent limitations. Spatial resolution in commercially available ultrasound does not adequately permit visualisation of the epineurium. Therefore the exact 3-D relationship of block needle and target nerve on a 2-D screen is uncertain at best. Modern 'ultrasound visible' needles further distort the picture by increasing the 'noise' generated by the needle, thereby improving needle visibility at the cost of the visibility of surrounding structures, including the target nerve. The danger in deliberately placing the block needle very close to the target nerve is inadvertent intraneural needle placement, which may result in inadvertent intraneural injection and nerve injury [10]. While it is not the intention of this talk to discuss the topic of intraneural injection, the take home message is that as we attempt to achieve USNB with small doses of LA thereby limiting the dose dependent LAST, the risk of intraneural injection increases. Technological solutions are required to address this issue.

Conclusion

The talk will discuss the above considerations and open the discussion on local anaesthetic dose and USNB. Table 1 summarises many of the studies addressing the topic of dose and USNB.

Table 1

Upper Limb Block	Author, Year, Journal	Study Drug	Study Type	Technique	Outcome
Interscalene	Bruin G 1996 RAPM Al-Kaisy 1998 RAPM Krone 2001 RAPM Riazi 2008 BJA Renes 2009 RAPM	Bupiv 0.5% Bupiv 0.125% Bupiv 3 conc. Ropiv 0.5% Ropiv 0.75%	Letter RCT RCT RCT RCT	Stim Stim Stim U/S U/S vs Stim	5 ml 10 ml 10 ml 5 ml 10 ml
Supraclavicular	Kapral 1994 A&A Chan 2003 A&A Soares 2007 RAPM Morfey 2009 Anaes Tran 2011 RAPM	Bupiv 0.5% Lido/Bupiv None None Lido 1.5%	RCT Vs Ax Series Technique Letter Dose-find.	U/S U/S U/S U/S U/S	30 ml 40 ml ?15 ml 33 ml 32 ml
Infraclavicular	Tran 2011 RAPM Sauter 2008 A&A Sandhu 2006 J ultrasound med	Lido 1.5% Mepiv 1.5% Lido 2%	Dose-find. Dose-find. Case	U/S U/S vs Stim U/S	35 ml 0.6ml/kg 15 ml
Axillary	Marhofer 2010 Anaes Harper BJA O'Donnell 2009 Anesthesiology	Mepiv 1% Lido 1.5% Lido 2%	Dose-find. Dose-find. Dose-find.	U/S U/S U/S	0.11/mm^2 2-3 ml 1 ml
Forearm Nerves	Eichenberger 2009 RAPM	Mepiv 1%	Dose-find.	U/S	0.11/mm^2

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Learning and teaching ultrasound guided regional anaesthesia: Pointers and pitfalls

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Introduction

Ultrasound guidance has revolutionised the practice of peripheral nerve block for anaesthetists. Once the preserve of a few dedicated enthusiasts, referred to dismissively as 'the green needle brigade', peripheral nerve block has become a truly viable alternative to general or neuraxial anaesthesia. In Ireland, the College of Anaesthetists has defined peripheral nerve block as a core clinical skill and has appointed a task force to advise on the creation of a curriculum to integrate ultrasound guided peripheral nerve block into the established specialist training programme. In principal, this might seem like a fairly straightforward process: decide what the trainees need to know and teach it. In reality the design of a proficiency-based curriculum for peripheral nerve block is a complex high-stakes process, which creates more questions than it answers.

In my talk, and briefly outlined in the accompanying paragraphs, I will discuss the considerations in proficiency-based curriculum design, identify some of the early goals and address the challenges that face us in the roll-out of such a programme.

At the beginning

What is a peripheral nerve block? What is an ultrasound-guided peripheral nerve block (USNB)? If you can answer these two questions, then please read no further. However think a little more carefully as to each of the components of an ultrasound-guided peripheral nerve block and you will then begin to grasp the complexity of this procedure that you may perform intuitively and instinctively several times each day. This is akin to asking: How did you drive to work today? There are a number of domains from basic knowledge, cognitive processing of received information, decision-making processes, procedural skills and technical execution of all of the above that is required to drive a motorcar on any journey from A to B. This is also true of USNB and thus an appropriate definition of USNB is the initial starting point in curriculum design.

At Cork University Hospital and University College Cork, Ireland, we have been busy asking these questions and examining ways in which the complex procedure that is USNB can be broken down into component parts.

Competence based Knowledge Space Theory [1]

The challenge in developing such a procedure lies in defining each skill while taking account of the many factors, which influence doctors' learning and performance. These include cognitive, motor, communication, and human (e.g. fatigue, anxiety and fear) factors. In other areas (including digital gaming and human resource management), an innovative theory, 'competence based knowledge space theory' (CbKST), has been successfully applied to enhance learning, assess competence and facilitate personalised learning. This theory is applied by developing a "problem set" designed to test all aspects of the practitioner's proficiency. The manner in which an individual practitioner copes with

the various problems provides a profile of his/her competence at a point in time. This profile (described using mathematical formulae) can be used to judge / monitor a trainee's progress over time, to compare practitioner's performance with a standard and, importantly, provide detailed feedback to the clinician to facilitate "personalised" learning.

Hierarchical Task Analysis (HTA) [2]

HTA is a technique borrowed from industry, which defines the end goal of a process in terms of a hierarchy of tasks and subtasks required to achieve the desired goal. To answer 'What is an ultrasound-guided axillary brachial plexus block (USgABPB)', HTA may be employed. HTA methodology facilitates task decomposition, including cognitive tasks, which would be carried out by an anaesthetist in performing USgABPB. Utilising this methodology USgABPB can be broken down into 257 discrete operations and sub-operations.

Errors and criticality [2]

It is obvious that novice/trainee anaesthetists do not behave or perform in a manner comparable with experienced or expert anaesthetists in the context of USNB. Again to use the driving analogy, learner driver behaviour differs significantly from that of experienced drivers and as such learners are more likely to make errors that lead to adverse consequences. Novice anaesthetists in the sphere of USNB are no different [2]. By identifying the common errors in novice behaviour observed during USgPNB, matching the HTA operation and ranking the error based upon their detectability and criticality, the curriculum design can be better informed as to what portion of the 257 discrete outputs from the HTA to focus upon. Systematic Human Error Reduction and Prediction Approach (SHERPA) and Failure Modes Effects and Criticality Analysis (FMECA) are two such error identification tools that we successfully applied to HTA outputs to identify the 'top 20' novice errors in USgABPB. (Table 1)

Table 1 Top 20 Errors in Novice USgABPB

HTA Operation NUMBER	ERROR DESCRIPTION	Criticality Index
2.5.4.3.3.1.4	In the event that the needle is poorly or not visualised while advancing it towards the target, the anaesthetist continues the advance the needle	490
2.5.4.3.3.1.1	In advancing the needle under ultrasound guidance, the anaesthetist believes the needle tip is visible when in fact it is not	461
2.5.4.3.3.2.4.2	In using a small bolus of local anaesthetic to confirm the needle tip is in an appropriate location, the anaesthetist incorrectly identifies visual cues as appropriate when they are not	437
2.5.4.3.3.2.2	Prior to depositing a bolus of local anaesthetic, the anaesthetist believes the needle tip is visible when in fact it is not	432
2.1.6.2.2	In finding the best needle trajectory to perform the block, the anaesthetist fails to check the risk of the possible trajectory to cause neural/other injury or vascular puncture	404
2.5.4.3.3.2.4.3	In using a small bolus of local anaesthetic to confirm the needle tip is in an appropriate location, the anaesthetist checks for the presence of inappropriate visual cues but fails to recognise them when they occur	403
2.5.4.3.3.1.6	In attempting to optimize the image of a needle which is poor/lost, the anaesthetist moves needle rather than the probe	394
2.5.4.3.3.1.5	In attempting to manipulate the ultrasound probe to optimize the image of a needle which is poor/lost, the anaesthetist fails to note the cues provided by examining the orientation of probe and needle at the skin surface	382

2.5.4.3.3.2.2	Prior to depositing a bolus of local anaesthetic, the anaesthetist fails to confirm the needle tip is visualised	374
2.1.5.1.3	In confirming the anatomy of the vessels in the axilla, the anaesthetist fails identify all veins	336
2.5.5.1	Having deposited what is believed to be sufficient local anaesthetic, the anaesthetist fails to be vigilant of signs of CNS toxicity	269
2.5.4.3.3.1.1	In advancing the needle under ultrasound guidance, the anaesthetist fails to check that entire length of the needle (including the tip) is visible	269
2.5.4.3.4.1	Prior to depositing subsequent doses of local anaesthetic, the anaesthetist fails to aspirate the syringe at appropriate intervals	246
2.5.4.3.3.2.4.1	Prior to depositing local anaesthetic around the target nerve, the anaesthetist fails to administer a small test bolus to confirm the needle tip is in an appropriate location	234
2.1.6.1.3	In finding the best location to perform the block, the anaesthetist checks for the ability to visualise the blood vessels in the area but fails to identify all of the significant vessels	227
2.5.4.2.6.1	In attempting to advance the needle towards the target nerve, the anaesthetist is markedly inaccurate	222
2.1.6.3	In finding the best needle trajectory to perform the block, the anaesthetist fails to scan proposed needle trajectory with colour Doppler to identify unsuspected blood vessels	187
2.5.4.2.5	Prior to advancing the block needle the needle, the anaesthetist misaligns the needle trajectory and the scanning plane of the ultrasound probe	180
2.1.5.1.3	In confirming the anatomy of the vessels in the axilla, the anaesthetist fails to identify any veins	163
2.5.4.3.3.2.1	Prior to depositing a bolus of local anaesthetic, the anaesthetist fails to aspirate the syringe	112

Metric Assessment and Tracking

Once the error has been identified, it is now possible to define precisely how that error might be identified and appropriate metrics applied. For example the error with the highest criticality index in table 1 involves the forward advancement of the block needle without adequate visualisation of the needle using the in-plane approach. This could be a simple yes/no with a pass/fail outcome: Did the trainee advance the needle when the needle tip and shaft were not visualised? Alternatively, with the design of needle tracking or video analysis it may be possible to determine the proportion of time during forward needle advancement the needle was actually visualised. This could then be matched to an expert derived proficiency score for direct comparison.

Definitions of Proficiency/Competency

Clinical competence might be defined as: 'The mastery of relevant knowledge and the acquisition of a range of relevant skills at a satisfactory level including interpersonal, clinical and technical components at a certain point of education...' [4]. Proficiency might be thought of as an extension of competency measured and determined over time. Therefore proficiency might be defined as: 'mastery of a specific behaviour or skill demonstrated by consistently superior performance, measured against established or popular standards.' [5] It is beyond the scope of this abstract to discuss the merits of proficiency versus competency based model of medical training. It is however desirable, in designing a curriculum, to acknowledge that skill and knowledge may decay over time. This may then be addressed and remediated within the curricular structure.

Simulation and Clinical Training

Simulation has become an integral part of most postgraduate anaesthesia curricula. By training in a simulated environment, novices can acquire skills in a setting where errors and critical events may occur in a consequence-free fashion. This enables trainees to acquire the necessary experiential knowledge, cognitive processes, communication skills and procedural skills to deal with real life procedures and critical incidents. Procedural skills training in surgery and interventional radiology have evolved in the sphere of simulation. High fidelity virtual reality simulators are available to train high stakes procedural skills without patient contact. In many instances real-time assessment of trainee performance is possible in the simulated environment, thereby potentially offering a component of credentialing or performance certification.

USNB is ideally suited to teaching in a simulated environment. It has been demonstrated that novices learn best when removed from the pressures and time constraints of a busy operating list and when they have dedicated time and space for learning procedural skills. A simulator (currently available gel-based models, meat phantoms or future virtual reality high fidelity models) may fill the gap between initial skills acquisition, repetitive deliberate practice and skills mastery prior to engaging with patients.

The Department of Health and the National Health Service (UK) have recognised the need to modernise the manner in which healthcare professionals are trained. It is likely that simulation and simulated environments within the clinical arena will become commonplace in the near future [6].

Integrated Learning Management Systems

Learning management systems (LMS) have been integrated into simulators, and add to the versatility and individualised nature of the simulated training environment. Using a unique user log-in it is possible to track individual performance over time and across many domains of competence. The LMS can assimilate procedural performance derived metrics and provide user feedback. The use of integrated virtual patient environments enables the LMS to track trainee performance in any number of circumstances and allows a comprehensive assessment of overall clinical performance, not simply procedural proficiency, in the simulated environment.

Assessment methods

In the absence of sophisticated tools to track and score decision making processes, needle trajectory, visualisation and ultimately the site of local anaesthetic deposition, how might trainee performance be assessed? Traditionally, unstructured mentor-style observation has been employed. In this model the trainee will have intensive supervision for a period of time, until such time as they begin to display attributes and skills that please the mentor. Gradually the mentor withdraws from a supervisory role toward an advisory role and finally a consultative role. The process is usually unstructured, user dependent and open to very significant inter-rater observational bias.

Formative assessment models provide a more structured approach to trainee performance. Regular structured feedback sessions are planned along a predefined training period, which allows the trainee to develop a sense of how they are performing. This ‘metacognitive awareness’ allows trainees develop reflective practice. Training outcomes and performance can be tracked over time. There are rating scales which have been used for research purposes to track individual performance over time, however their reliability is questionable given problems such as poor initial validation and limited inter-rated reliability [7].

Summative assessment or the end of term examination may be a convenient way to assess learning and provide a snapshot as to whether a trainee has attained a required standard. This may take the form of an OSCE-type scenario where the trainee, having completed the modular training in USNB, undertakes a multifaceted examination to determine adequacy of learning. The advantage of this approach is that a single assessment intervention will determine the quality of learning. However such examinations seldom accurately reflect actual performance and are therefore of limited external validity.

Recently, groups have focused on PNB outcome data tracked using CUSUM scoring. CUSUM tracks successes and failures in processes over time and alerts to inappropriately high process failure rates. Unfortunately when applied to USNB the process outcome measured is block success or failure. Is there an appropriate or acceptable block failure rate? If so why are individual practitioners blocks failing where others don't? Within CUSUM there is no way to determine whether individual performance was 'satisfactory' or in adherence with best accepted standards. Therefore tracking performance with a blunt instrument such as CUSUM moves away from competency/proficiency based models. The danger in adopting such a tool is that training metrics which may be used to improve the training environment for both the individual and the collective is lost.

The Curriculum Design and Delivery
The curriculum design for USNB might therefore incorporate the following elements:

- Cognitive, knowledge based elements
  - Ultrasonography, physics, image interpretation/optimisation
  - Clinical Anatomy
  - Sonoanatomy
  - Clinical Pharmacology
  - Equipment
- Procedural/technical skills
  - Ultrasonographic skills, manipulating the ultrasound machine
  - Needle/ultrasound interaction
  - Block performance
  - Block assessment
- Communication skills
  - Patient selection
  - Pre-block interview/anxiolysis
  - Staff/assistance interactions
  - Patient interaction during and following block
- Human factors
  - Managing personal stress
  - avoidance of anxiety transfer from healthcare professional to patient
  - Intra-operative OR environment management
  - Provision of anxiolysis (non-pharmacological/pharmacological)

In Ireland it is planned to deliver this curriculum on a phased basis to trainees over the course of their 7-year specialist training programme in four distinct phases:

Foundation level

a. Core blocks to include Axillary Brachial Plexus, Femoral and Popliteal Sciatic

b. Delivered in a one-day small group problem based setting outside of the teaching hospital.

c. Key cognitive and procedural elements covered

Intermediate Level 1

a. Core blocks as in the foundation course, practiced in the clinical arena under direct specialist supervision over a 2-4 week intensive module.

b. Formative structured assessment process to incorporate matched modular goals with proficiency as measured by modified global rating scale.

Intermediate Level 2

a. Extension of core blocks to incorporate more advanced techniques: interscalene/supraclavicular brachial plexus, thoracic paravertebral block, transversus abdominis plane block (non-exhaustive list)

b. Formative structured assessment process to incorporate matched modular goals with proficiency as measured by modified global rating scale.

Masters Level

a. Designed for those who wish to pursue USNB as a sub-specialist interest. A Fellowship level programme designed to allow the experienced practitioner opportunity to develop additional USNB skills and participate in clinical and educational/translational research.

Summary

The design and delivery of a comprehensive training process for USNB is tantalizingly close. New technology will play an increasingly important role in both training delivery and assessment of learning. Assembling the building blocks of an integrated USNB curriculum will facilitate its' safe and widespread use.

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Manual skills training - the Science

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Introduction

Manual skills form a sub-set of the wide range of the skills required in anaesthetic practice; these skills range from clinical examination to invasive procedures. The way in which trainees learn to perform manual skills has been described in the anaesthetic literature [1-7]. However coverage in the psychology literature is significantly more comprehensive and is applicable to our everyday practice.

Power law of learning

The general pattern of improvement when practising a manual skill is common across skills and trainees. Initially there is rapid improvement and, as practice continues the rate of improvement decreases. Improvement continues to occur albeit slowly towards an asymptote which represents, "best possible performance".

This phenomenon is described as the "Power Law of Learning", because it is represented by an exponential relationship. Perhaps the most famous example of this law was described by Crossman who looked at the time taken to manufacture cigars in a Cuban factory. He followed workers over a number of years covering the production of 10,000,000 cigars. He demonstrated that the time taken to produce a cigar continued to decrease toward an asymptote representing the cycle time of the machine used. This phenomenon has been shown to hold across a variety of disciplines [8].

Three phases of learning manual skills

Whilst there is a demonstrable and continuous improvement in performance during practice of a manual skill, distinct stages can be identified. Understanding these stages may help to target teaching [9].

Stage 1

> Imagine a trainee who is nervously trying to place an intravenous line for the first time, the skin cleaned, IV hovering over the vein, palpating a third or fourth time, focusing entirely on the task at hand, unaware of what else is occurring in the room, making a tentative insertion, getting a flash back but passing through the vein, making abortive attempts to salvage the insertion...

During the first stage of learning a motor skill, a trainee is solving the problem; "How do I put together a series of movements to allow the designated outcome?" The solution to the problem is a motor program. In order to solve the problem the trainee must have a clear mental picture of what they are trying to achieve, of what defines success. With each attempt at the motor task, they must examine how their performance differs from their mental picture and implement changes to close the gap.

During this first stage, performance of a motor skill takes up a large proportion of the trainee's attentional capacity; they are unlikely to be able to attend to other issues concurrently. One characteristic of the first stage is that trainees will often run an internal monologue, describing what they think they should be doing, as they are performing the task [10].

Stage 2

> Under normal circumstances the resident appears to perform well, he has a good grasp of the series of events that needs to occur his movements are relatively smooth; he has a good chance of success. However, when things get a little difficult, he may be easily flustered and his level of performance decreases.

During the second stage of learning a trainee's movements will appear more certain and fluid. They have created a motor plan that they can enact under normal circumstances. Utilising a motor plan allows the trainee to use their attentional capacity for other purposes. If the procedure is particularly difficult or the stress level is particularly high, the trainee may become flustered and perform poorly. [They are unable to adequately adjust their motor plan to cope. The motor problem must now be solved again, once more this utilises the trainee's attentional capacity [10].

Stage 3

> The experienced consultant makes the procedure look easy under most circumstances, she is able to focus on the events in the surrounding environment whilst intubating. There is very little that can disturb the progression of the procedure, which is performed quickly and efficiently. Errors are easily noted and corrected.

In the third stage of motor learning the trainee's motor plan has become flexible. The motor plan can be utilised under a variety of circumstances. Movements are fluid, confident and adaptable and errors are easily recognised and dealt with. In this situation the anaesthetist has a broad range of motor solutions that can be applied to cope with unexpected situations [10].

Individual Differences

The descriptions above generalise learning of manual skills. There are of course individual differences. Not everybody can be an Olympian!! There are genetic contributions to initial aptitude, rate of learning and the "optimum level" of performance that can be reached. Importantly poor aptitude does not necessarily mean that a trainee cannot learn and achieve a high level of competency [11].

Simulation

Simulation allows a motor skill to be practised without the inherent pressures of clinical environment. It also allows trainees to gain a level of competence before performing procedures on patients! A good simulator will re-create the target skill in the target environment. The fidelity of the simulator does not have to be high [12].

The way practice is undertaken has an impact on performance and learning. Performance is the ability to perform a task at a given point in time; learning refers to an improvement that is sustained over time. For example if a trainee practices a procedure 10 times in a row they are likely to do better on the tenth effort than on the first; this reflects improved performance. If they still do better after 2 days break, this reflects learning [13].

Learning is promoted by the mental effort of "working out" how to perform the motor skill. This can be promoted by teaching multiple motor skills in a simulator session in a random fashion (random practice) or by practising in discrete blocks, say 2 attempts daily over a week (blocked practice), rather than 10 attempts in a single sitting (massed practice) [14].

Some skills are best broken down into components; others need to be practiced as a whole. Generally serial skills can be broken down, whereas skills that are performed in parallel should be practiced as a whole. For example, it is necessary to practice long axis ultrasound needling as a whole skill, as holding the probe steady and inserting the needle in plane are skills that occur in parallel.

The relative difficulty of the task presented to the trainee and the stress under which the task is undertaken both have impacts on the trainee's performance.

Feedback

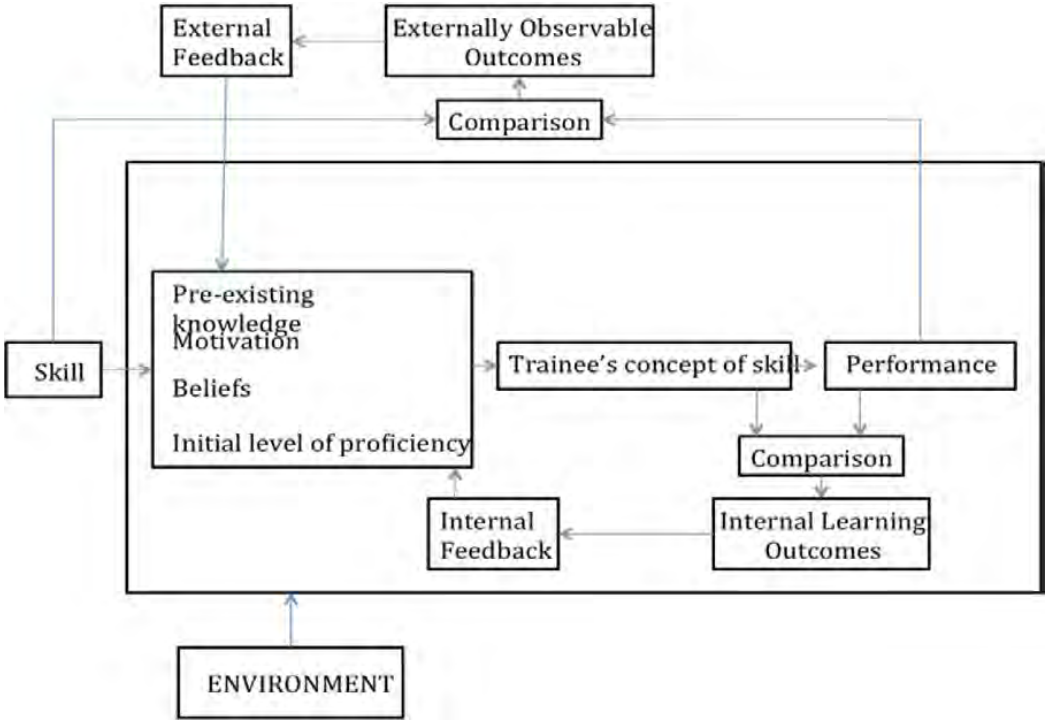

Fig 1. Self regulated learning and feedback principles, adapted from Nicol and Macfarlane-Dick [15]

The above model can be used to describe how feedback impacts on improvement of a manual skill. The trainee's concept of the skill is developed as a combination of a number of personal attributes they bring to the learning experience. Internal feedback occurs when a trainee compares their actual performance to their concept of the skill. External feedback can be delivered by an observer who compares the trainee's performance to their own internal concept of how the skill should be performed. Good quality external feedback helps the student to trouble shoot their own performance and self-correct. Ideally the goal of feedback should be to promote the trainee's ability to improve on their own [15].

A critical role of a supervisor is in control of the environment in which the manual skill is performed. Trainees in the early stages of learning may be unable to monitor a patient's physiology, provide reassurance or interact with other members of the treating team, as all their attention is taken up by performing the skill. These tasks can be performed by the supervisor and then slowly given to the trainee as their competence increases.

One key area is ensuring that there is congruence between the trainee's concept of the skill

and the skill as it should be performed. Demonstration of the skill by “exemplars of performance” may help create a valid concept, asking trainees to critique their own performance before giving external feedback, may point to deficits in their own thinking and promote self learning. Providing feedback on the performance of other trainees may equally be useful.

1. Talking a trainee through performance of a skill should be avoided, as it may inhibit learning the sequence of events during performance of a skill.
2. Feedback provided during performance may distract a trainee.
3. Feedback should be delivered soon after the skill is performed.
4. Criticism offered should be constructive, providing advice about how attributes of performance can be improved. Praise for positive aspects of performance should be offered alongside critique.
5. Feedback points should be limited to avoid over whelming trainees with information.
6. Feedback can have a significant effect on the motivation of the trainee!

Expertise

Defining expertise is difficult, however most anaesthetists could probably think of colleagues whose skills stand out. One attribute which is common to people who are defined as experts is that they have invariably practiced a lot. In fields such as chess and music, “a lot” is loosely defined as 10,000 hours, approximately 3 hours a day for 10 years. Volume of practice is only one aspect; the quality of the practice is also important. Good practice involves constant analysis of performance, definition of weaknesses and practice focused on these weaknesses. This type of practice has been labelled as “deliberate practice” by Ericcson [16].

Coaching

In a recent article in The New Yorker, Atul Gawande proposed that surgeons could benefit from coaching. His argument was based on the fact that elite sports people and musicians use coaches to improve their performance. In the article he re-counts the positive experience of working with another surgeon as a coach [17].

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Educating and credentialing - the British experience

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Introduction

Ultrasound-guided regional anaesthesia (UGRA) has been in general usage for approximately 10 years. This has coincided with a renaissance in regional anaesthesia. This may be partly attributable to the increased efficiency (reduced doses of local anaesthestic, rapid block onset, improved block quality) and the ability to place blocks without dependence on landmarks that may be seen when using ultrasound compared with other nerve localisation methods [1-4].

Since ultrasound has become an important method for nerve localisation and the delivery of regional anaesthesia, we must ask the questions, how safe is it and what training is required to deliver it competently? There is very little evidence regarding the relative safety of UGRA compared to traditional nerve location techniques, nor is there likely to be; as the rates of complications due to the performance of regional anaesthesia are so low that demonstrating statistical differences between techniques is extremely problematic. However, this does not mean that we should be complacent when considering the safety of practitioners learning to perform techniques under ultrasound-guidance.

One would assume that ultrasound should make the delivery of regional anaesthesia safer, as we are guiding the needle to the target and injecting local anaesthetic under direct vision. Indeed, ultrasound is extremely sensitive for detecting intraneural injection [5] and can also detect intravascular injection of local anaesthetic [6-7]. With this in mind, one may conclude that ultrasound is the safest technique and indeed the gold standard for regional anaesthesia [8]. However there are a number of reports of complications occurring following needle-guidance with ultrasound and studies looking at post-block complications may show little difference between nerve stimulator and ultrasound-guided nerve blocks [9]. Complications may occur due to operator error when performing UGRA; if the needle tip and nerve are not observed at all times during block placement, then needle misplacement may occur, often leading to over-insertion of the needle. These errors will occur more frequently when learning UGRA [10]. A thorough knowledge of the anatomy of individual nerves and nerve plexuses and the ultrasound appearance of those structures (sonoanatomy) is also required before undertaking ultrasound-guidance; without this, the risk of needle malposition into a nerve or vessel may be greater than when using nerve stimulation [11].

Training and Education

Clearly, UGRA is now at a stage where practice is becoming widespread and as a specialty, we need to ensure that regional anaesthesia is delivered to the highest possible standard of governance.

In 2009, the American Society of Regional Anesthesia and Pain Medicine and the European Society of Regional Anaesthesia and Pain therapy produced their joint guidelines for education and training in ultrasound-guided regional anaesthesia [12]. This timely publication

was drawn-up following a consultative process by a group of experts in the field from both societies that formed the Joint Committee. The guidelines contain a suggested curriculum, training pathways and suggestions for demonstrating competency.

The document begins by describing indications and the scope of practice for using ultrasound, and describing ten tasks that are undertaken when performing an ultrasound-guided nerve block. The document then describes four major skill categories: (1) understanding device operations; (2) image optimisation; (3) image interpretation; and (4) visualisation of needle insertion and injection of the local anaesthetic solution. Within each of these categories, the Joint Committee defined a number of skills.

Two training pathways were then described; a practice pathway (for physicians who have completed anaesthesia training) and a residency-based pathway (for anaesthetists in-training). The practice-based pathway describes initially gaining the skill sets already mentioned, through an accredited CME event, followed by practice scanning techniques and needling in phantoms. Ideally, time would be spent with experienced individuals before finally incorporating UGRA into pre-existing regional anaesthetic practice. The residency-based pathway would fit flexibly into the training programme with an initial didactic component addressing the four skill categories described above. Then enough experience should be attained performing a variety of blocks to attain competency in these skill categories. Residents would be encouraged to record video clips and still images for review with trainers to gain feedback on procedures performed.

The guidelines also recommend the appointment of an UGRA coordinator, whose purpose is to implement, oversee and quality control both pathways of UGRA training. The coordinator should use direct supervision, recorded image review, logbook review and other information to help them improve quality of their training programmes.

In the UK, a guidance document has now been produced entitled; ‘Ultrasound in Anaesthesia and Intensive Care: A Guide to Training’, by a joint working party of the Association of Anaesthetists of Great Britain and Ireland, the Royal College of Anaesthetists and the Intensive Care Society. This document covers all areas of anaesthesia ultrasound practice including UGRA. The document was published as a guideline in July 2011 and is available for download from the AAGBI website.

I believe the challenge in education of UGRA is the fact that the curriculum to be covered is actually very large. Consider the skill categories involved: (1) understanding device operation (physics of US, individual machine operation); (2) image optimisation (scanning technique); (3) image interpretation (sonoanatomy of the many areas of interest); and (4) visualisation of needle insertion and injection of the local anaesthetic solution (needling technique). Clearly, there is a large amount of information to be learned, anatomy to apply and hand-eye skills to master. In my experience, I think this has presented individual schools of anaesthesia (including my own) with a big challenge. How do we find the time to teach all these aspects to all our trainees and senior colleagues new to the practice?

In the UK, we have been running nationally advertised courses for nearly 10 years. These courses are now run through our national society: Regional Anaesthesia UK, and typically teach 24 delegates over two days. This serves as an introduction to UGRA and gives delegates an overview of the curriculum. However, these types of courses do not address the issue of reaching *all* UGRA novices. I believe we can go some way to achieving this major undertaking by developing computer-based remote learning packages, allowing trainees to

undergo self-directed learning, with supervisor input at specific points during the process. This type of approach will allow trainees to cover (with assistance), all aspects of the curriculum.

Competency

In many ways, assessing competency is the most difficult part of the process. The implementation of a curriculum and training programme as described by the joint societies is possible (as described above) and many schools of anaesthesia and hospitals are already putting these recommendations in place.

The ASRA/ESRA and UK guidelines did not make specific recommendations for assessing competency as they recognised that there exists a large spectrum of practice internationally, and individual institutions must develop their own processes for ensuring individuals' level of competency before providing them with practising privileges in UGRA.

So how should we assess competency in those who have undergone training and are wishing to perform the technique in their practice? Large teaching hospitals may well find this process simpler as they may have a teaching structure already in place. Smaller hospitals without trainees may find it more difficult.

There are a number of summative methods by which competency can be assessed. Cumulative sum analysis (CUSUM) is a sequential analysis technique and has been used to assess task competency in various surgical specialties [13-16] and anaesthesia [17-20]. CUSUM has been popularised for the assessment of regional anaesthetic tasks, I will therefore mention it here.

CUSUM may be described as

$$S_n=\Sigma (X_0-X_i)$$

where X_0 is the set success rate for a procedure
and X_i is either 0 (failure) or 1 (success)

Let us consider a regional anaesthetic task and set an acceptable success rate for the task of 90%. Applying CUSUM to the task will present a value for S_n that will decrease by -0.1 or increase by 0.9 for a success or failure of the task respectively. If the operator has one failure in ten procedures, he or she will maintain an overall horizontal plot. If the operator is more successful (than 90%) the plot will have an overall negative gradient and equally, if the operator becomes less successful (than 90%), the plot will develop a positive gradient. CUSUM is therefore a potentially useful way for practitioners to monitor their own practice, but when applied to UGRA, there are some disadvantages. A CUSUM plot of an individual's UGRA practice may provide information about the success rates of their blocks. However, as inferred by the training guidelines described above, UGRA involves a number of integrating skill sets to be performed competently. The success or failure of a block does not necessarily show that the practitioner's technique was competent; for example, they may well have inadequate needle visualisation risking needle overshoot and nerve injury, even though the outcome is block success. For this reason, CUSUM can only form part of the assessment of an individual's competency to perform a complex task such as UGRA, and therefore has been termed a 'square peg in a round hole' [21]. The other issue is that an individual's CUSUM score will be affected severely by early failures and therefore may only declare very late the novice who has actually become competent. This has led to various manipulations of CUSUM

analysis to improve its performance, and tries to provide the user with an answer to when the individual has achieved competency [22]. The advantage of a CUSUM analysis is that it can form part of an individual's self-assessment of their practice.

Direct assessment of competency is probably required to satisfactorily judge an individual's ability to perform UGRA due to the multiple skills sets that are involved. The Royal College of Anaesthetists in the United Kingdom have produced a Direct Observation of Procedural Skills (DOPS) form that covers assessment of all practical skills required by anaesthesia trainees during their training. This is an example of a non-specific tool, and would need local adaptation to properly assess UGRA.

Quantitative assessments of UGRA performance and skill sets can be made, such as the composite accuracy score described by Sites et al. which scored the number of errors (e.g. needle not visualised during advancement) image quality, number of attempts, block failure and intravascular puncture [10]. They also made qualitative assessments of quality-compromising behavior. While these types of specific assessment tools can provide a detailed assessment of the skill sets involved in UGRA, they will be time consuming in their delivery, and if applied to a large training programme will require training of assessors to ensure consistency in assessment standards.

Summary

The use of ultrasound has, I believe quite rightly, become widespread in clinical practice. The 2009 publication of the joint American Society of Regional Anesthesia and Pain Medicine and the European Society of Regional Anaesthesia and Pain therapy guidelines and the 2011 Association of Anaesthetists of Great Britain and Ireland guidelines have laid out a curriculum for training and recommended that a structure be put in place in individual institutions for delivering that training. The role of the ultrasound-guided regional anaesthesia coordinators will be paramount, not only in the local delivery of the training, but also in the more challenging role of ensuring that this important technique is delivered effectively and safely to the benefit of our patients. I believe that national leaders will be able to play a role in developing the training pathways that are 'deliverable' in local schools of anaesthesia.

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Where to from here in training and education?

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Introduction

The future direction of training and education in ultrasound guided regional anaesthesia (UGRA) is a controversial area, as there are many different opinions but little good evidence. Ultrasound is not currently considered a conventional part of anaesthesia practice and is not yet entrenched within the ANZCA curriculum. For this reason there has been a call by some for additional competencies and accreditation procedures. However, this can only follow adequate training, which still remains variable in quality. Also, we do not yet know how, or what, to assess before determining that someone has achieved competency. Much more research is required to as we continue to introduce the modality of ultrasound into anaesthesia practice. One important aspect to consider is that we use ultrasound in a different way to many other practitioners. Whether for regional anaesthesia or vascular access, we are using it simply as a *procedural* aid, much like a nerve stimulator or laryngoscope. This contrasts heavily with echocardiography and radiology where ultrasound is being used for *diagnosis*. This should change the level of requirement for separate accreditation.

International guidelines

The American and European Societies of Regional Anaesthesia (ASRA and ESRA) formed a joint committee to produce recommendations for education and training in ultrasound guided regional anaesthesia (UGRA) [1]. In this article they described core competencies but did not give advice on assessment or accreditation. This is unsurprising given the paucity of information on learning curves in UGRA. Shortly afterwards this was followed by an article defining guidelines for Fellowship training in UGRA [2]. This also avoided the area of assessment and accreditation.

Assessment of competency

Four stages of competency have been described:

1. Unconscious Incompetence – the person neither understands nor knows how to do something, nor recognises the deficit, nor has a desire to address it.
2. Conscious Incompetence – the person does not understand or know how to do something but recognises the deficit.
3. Conscious Competence – the person understands / knows how to do something but demonstrating the skill or knowledge requires a great deal of concentration. These are often the best teachers as they know exactly what they have to do to achieve the task.
4. Unconscious Competence – the task becomes "second nature" and can be performed easily. They may or may not be able to teach others as they no longer have to think about exactly what manoeuvres are needed to complete the task.

There are several studies examining skill acquisition in UGRA.

Sites showed that errors in UGRA decreased over time but that there was still an average of 2.8 errors per block even after performing 60 assorted blocks. Does this mean we are still not competent? How many are needed? Do we need 60 of each block or is there skill transfer between different blocks? It is also known that the acquisition of basic skills such as needle visibility and injection of fluid around a simulated target can take 37-109 repetitions [3].

Margarido showed a rapid learning curve for ultrasound assessment of the lumbar spine [4]. However, this is not a complete technique and many of the errors referred to by Sites relate to the needle insertion and guidance, which was not explored in the Margarido paper.

A Canadian group have just demonstrated that adding a simple hour long training session dedicated to needling and proper hand eye co-ordination, significantly improved block success rates (51% vs. 64%) and development of proficiency over a 3 week period (40% vs. 80%) [5]. In this study proficiency was described using CUSUM curves with an “acceptable” failure rate of 0.3 and “unacceptable” failure rate of 0.6. Are these rates at a level our patients would consider “acceptable”? Whatever your opinion on the actual rates, courses that give participants realistic needle practice, rather than simple scanning on live models are therefore more likely to result in changed practice [6].

Objective assessment tools such as Anaesthetists’ Non-Technical Skills (ANTS) or mini clinical exam (MiniCEX) may be introduced. However, there is still much we do not know about their use. When should they be used? How many times? What training have the assessors had? We know that it is hard to train assessors using these tools [7]. It can also be hard to get the assessors to agree on what is safe or not [8]. These factors all serve to complicate assessment.

Limitations of competency assessment

At what stage is someone deemed to be “competent” to perform UGRA and be accredited? Should this be based on success rates or complication rates? Should it be subjective or objective?

With all the unknowns, it is not unreasonable to ask whether we need, or want, competencies. Some may argue they serve to protect the anaesthetist, protect the patient, increase emphasis on safety or promote anaesthesia. However, what of the person who has not undergone a formal program or assessment? They may have been performing blocks for years and be very good. What if they then have a complication? Will the anaesthetic community support them? Will the requirement for additional assessments stop the average person doing some blocks they feel comfortable with? Will it make UGRA exclusive rather than inclusive? Our patients will ultimately be the losers with poorer quality of analgesia.

Conclusion

Many questions remain unanswered and until these are addressed we should not attempt to implement any formal program of assessment or accreditation, if we need them at all.

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Regional anaesthesia in the ANZCA curriculum

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Following the ANZCA decision to review the curriculum the college established a committee of fellows to complete the task. The purpose of this was to overhaul the Fellowship and to bring it into line with professional and community expectations. This curriculum review-working group (CRWG) then undertook an extensive consultation process seeking input from fellows, trainees, the wider medical community and the general public as to what their vision of a FANZCA should look like, and how they should be trained.

These submissions were carefully considered and consolidated by the CRWG. Once these comments were collated and distilled the group then worked with College educators to incorporate the CANMEDS model of medical education into a concept for a rejuvenated curriculum. The CANMEDS model recognises the many roles that an anaesthetist may play in their professional life and includes the following headings:

- Medical Expert
- Communicator
- Collaborator
- Manager
- Health Advocate
- Scholar
- Professional

Further details from http://www.anzca.edu.au/trainees/curriculum-revision-2013

Recommendations based on these comments and work was then sent to College Council for their consideration, which was largely accepted.

College Council then established several working groups for the curriculum revision. These groups included:

Curriculum Redesign Steering Group

This group's role is to oversee all aspects of the redesign and implementation of the revised training programme. This includes the development of a revised curriculum structure and curriculum content. The group lead the authoring process with the curriculum authoring groups, with CRSG Fellow members chairing two groups each.

Curriculum Project Governance Group

This group oversees the development of the operational aspects of the Curriculum Revision project.

Curriculum Project Coordination Team

This was formed in May 2011 to coordinate the implementation of the new training programme from an operational perspective. The team has a project management and a communication focus and works primarily with CRSG and CPAG to support coordination of the overall project.

Curriculum Project Advisory Group

This provides operational advice to the CRSG, to ensure effective and efficient implementation of the revised ANZCA training programme, including development of operational and administrative systems to support the new programme and retirement of the current programme.

Curriculum authoring groups

The 10 curriculum authoring groups (CAGs) were each responsible for writing course content in a specific topic area and developing recommendations around assessment, volume of practice and clinical experience requirements and incorporation of the CANMEDS model. The official involvement of the CAGs ended in December 2010, with a number of members choosing to continue their work into 2011.

The next step is to integrate current trainees into the new curriculum. There is a series of documents detailing how this will be completed and is also available for the above web page. These topics covered are:

- Transition principles for Basic Trainees in 2013
- Transition principles for Advanced and Provisional Fellowship Trainees in 2013
- Transition principles for Basic and Advanced Trainees in Extended and Interrupted Training

The new curriculum involves much more continuous assessment and workplace based assessment. The primary exam will in the future only be able to be undertaken by accredited trainees, thus removing it as a screening tool for entrance to training (which it was largely useless at).

Trainees will transition through three distinct phases from Introductory (first six months) to Basic (next 18 months and completion of the primary) to Advanced (final 3 years and fellowship exam).

With regard to Regional Anaesthesia the new curriculum now has a continuous focus on several Core Topics or Clinical Fundamentals:

1. General anaesthesia and sedation.
2. Airway management.
3. Regional and local anaesthesia.
4. Perioperative medicine.
5. Pain medicine.
6. Resuscitation, trauma and crisis management.
7. Safety and quality in anaesthetic practice.

There will also be **specialised study units** focusing on the care of patients requiring:

1. Head and neck, ear, nose and throat (ENT) and dental procedures.
2. Ophthalmic procedures.
3. Neurosurgery and neuroradiology.
4. General surgical, urological, gynaecological and endoscopic procedures.
5. Thoracic surgery.
6. Cardiac surgery and interventional cardiology.
7. Obstetric anaesthesia and analgesia.
8. Vascular surgery and interventional radiology.
9. Orthopaedic surgery.
10. Intensive care.
11. Paediatric anaesthesia.

12. Plastic, reconstructive and burns surgery.
(NOTE: Study required, clinical experience optional.)

Provisional Fellowship will consist of optional units which are pre-approved by the College and from which a trainee may choose OR a process by which a trainee may propose their own course of study requiring prospective approval by the College.
The list of unit options could include further practice:

1. As a generalist anaesthetic specialist or in areas of sub-specialist practice.
2. In specific settings such as rural, retrieval or overseas anaesthetic practice.
3. In non-medical expert roles such as research, teaching or management.

This new curriculum will require greater input from Fellows, in both teaching and assessment. It is hoped that this will not be difficult to institute. Many problem-based learning packages will be developed to assist with exploring the CANMEDS and Clinical Fundamentals with the trainees.
There will also be a greater use of workplace based assessment and use of devices such as the Mini CEX for competency based assessment. There will be no formal project required.

This new approach and new tools will present some challenges to us all as it represents a change to our practice. It will however ensure a more comprehensively trained Fellow who is assessed and trained in much more than just how to give an anaesthetic!

Sono-anatomy of the neck and clinical pearls

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Senior Clinical Lecturer, University of Melbourne

This presentation will review the anatomy and sonoanatomy of the neck, with emphasis on features applicable to the performance of brachial plexus regional anaesthesia. There is considerable variation of nerves and vessels in the neck; the common variants will be described, which has practical implications on modifying the block technique to minimise complications and improve efficacy.

1. Brachial Plexus Anatomy in the Neck

The brachial plexus is formed from the anterior rami of spinal nerves emerging from the intervertebral foramina of cervical vertebra 5 to 8, and the first thoracic vertebra. Occasionally contribution to the brachial plexus may occur from C4 (prefixed brachial plexus), or from T2 (post-fixed brachial plexus).

C5 and C6 combine to form the upper trunk, C7 continues as the middle trunk, and C8 and T1 combine to form the lower trunks. The nerve roots and trunks travel between the scalenus anterior and medius muscles, and may produce the classical 'traffic light sign' seen with ultrasound at the interscalene level.

Each trunk divides into anterior and posterior divisions at some point in the posterior part of the neck, and together they form the 'bunch of grapes' appearance of the supraclavicular brachial plexus seen with ultrasound at the base of the neck.

Further distally, the divisions combine to form the medial, lateral and posterior cords of the brachial plexus in relationship to the axillary artery posterior and inferior to the clavicle.

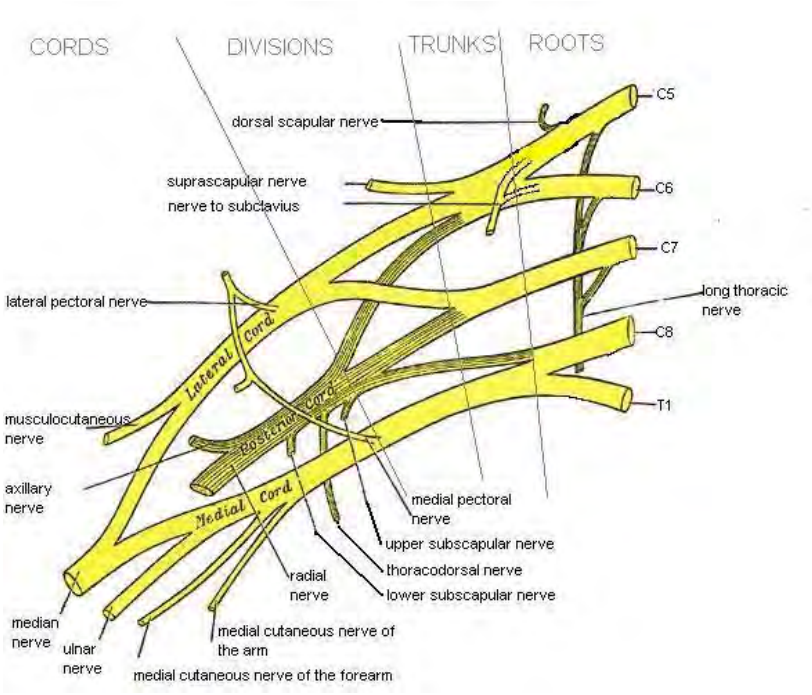


Figure 1. Usual arrangement of the brachial plexus [1]

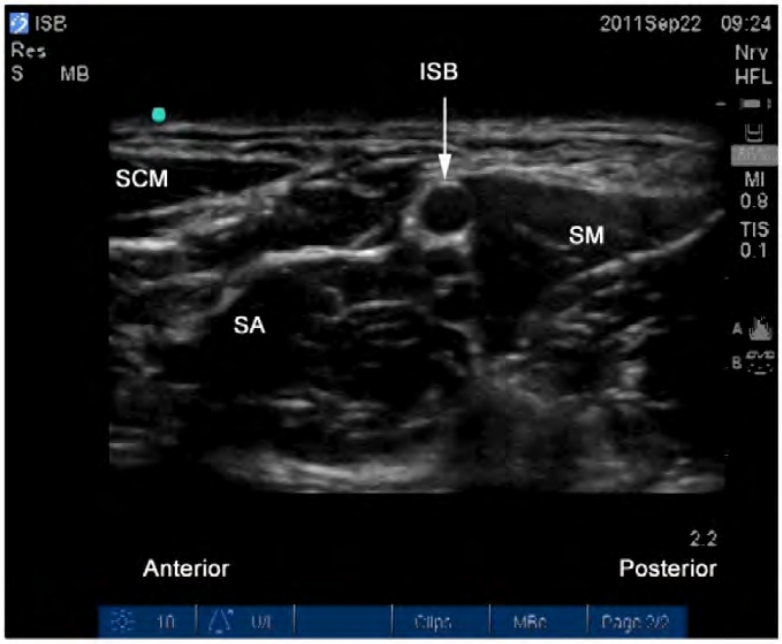


Figure 2. Typical brachial plexus arrangement at the interscalene region. ISB = interscalene brachial plexus with upper, middle, lower trunks. SM = scalenus medius. SA = scalenus anterior. SCM = sternocleidomastoid muscle.

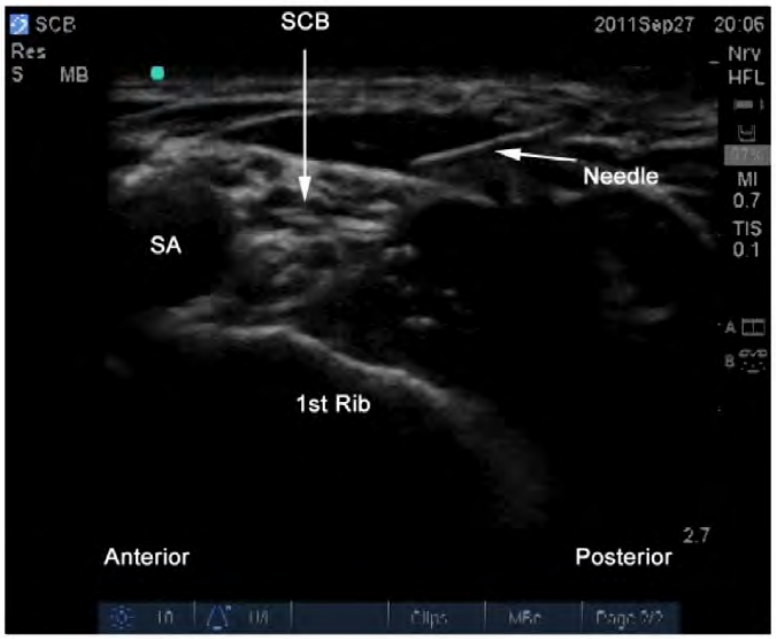


Figure 3. Typical brachial plexus arrangement at the supraclavicular region. SCB = supraclavicular brachial plexus. Note the bunch of grapes appearance with multiple echogenic nerves in a posterolateral position behind the subclavian artery (SA), and above the 1st rib. A needle is visible in-plane.

2. Common Variations of the Brachial Plexus in the Neck

In a small cadaver study, only 32% had the 'traffic light' configuration at the scalene muscles [2]. The most common variation is found in the upper trunk, and the most common type of upper trunk variation is the C5 and/or C6 roots passing through or superficial to the scalenus anterior muscle. In two small volunteer studies, 11-13% of their subjects had this variation [3,4], and in a larger cadaver study 25% of their specimens exhibited the C5 root piercing through or lying anterior to the scalenus anterior muscle [5].

Other upper trunk variations that were observed include distinct C5 and C6 roots that do not unite to form an upper trunk. The upper trunk may also be distinct and not adjacent to the middle trunk at the level of the cricoid cartilage, physically separated instead by what appears to be a reflection of muscle fascia but still within the interscalene groove.

A known connective tissue band lies adjacent to the scalenus anterior muscle; it may sometimes include an accessory muscle belly and termed as the scalenus intermedius. The presence of this muscle may also cause variation in the course of the brachial plexus.

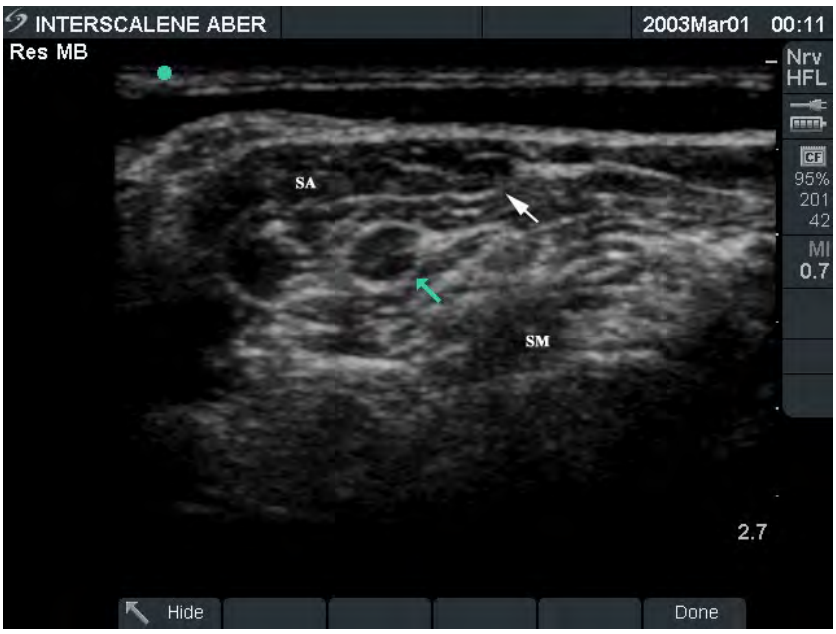
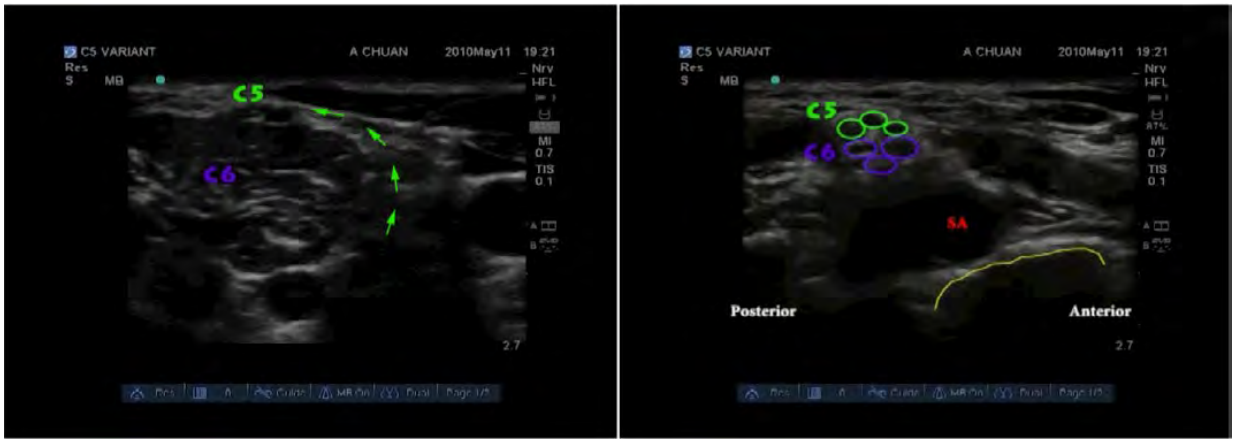


Figure 4. SAX view of interscalene plexus. SM = scalenus medius. SA = scalenus anterior. White arrow points to upper trunk. Blue arrow points to middle trunk. Note the physical separation of the trunks within the interscalene groove.



Figures 5 and 6. Still frames from a video loop of the C5 root passing through and superficial to the scalenus anterior muscle. Figure 5 is at the level of the interscalene groove, where the C5 root has travelled around the scalenus anterior muscle (arrow paths) to meet with the C6 root. Figure 6 shows the same plexus more distal at the supraclavicular level, where each root has divided into smaller divisions and nerves; however the C5 and C6 roots have not merged into a single upper trunk and remain visible and easily distinct. SA = subclavian artery

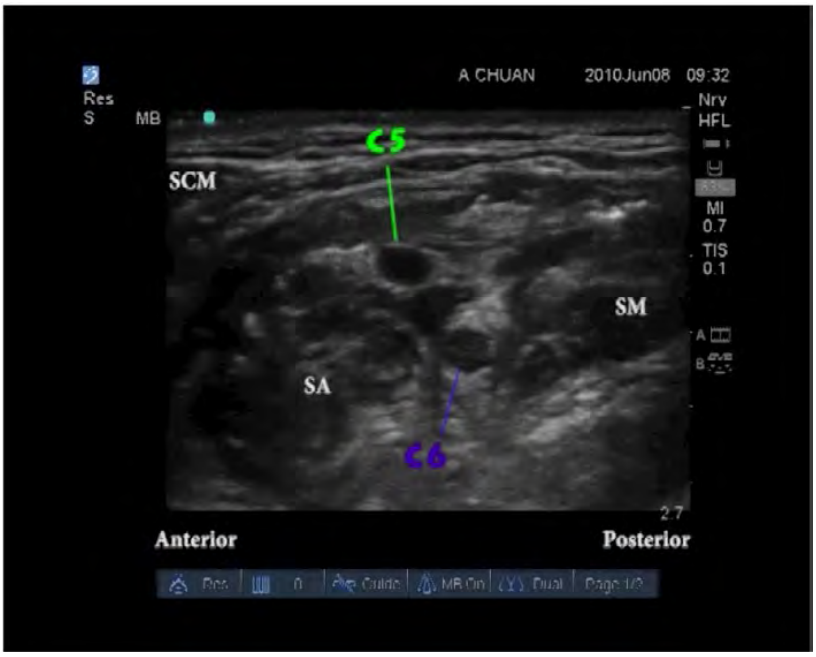


Figure 7. Still frame from another video loop of a variant C5 root distinct and separated from the C6 root. This C5 root will also move anteriorly and superficial to the scalenus anterior muscle when it is traced back proximally to the intervertebral foramen. Note this still frame was taken post-interscalene block; attention must be paid to ensure optimal local anaesthesia spread during ultrasound guided block given the variant anatomy.

3. Other Nerves Visible Using High Frequency US

3.1 Suprascapular nerve

This nerve branches off the upper trunk at some point in the low interscalene region and accompanies the rest of the brachial plexus until diverging below the trapezius and supraspinatus muscles towards the suprascapular notch. It is usually accompanied by the suprascapular artery. It supplies motor fibres to supraspinatus, infraspinatus, and teres muscles. It supplies important sensory afferents to the shoulder joint. It can be visible branching off the upper trunk at the superior border of the trapezius while it is still in the posterior triangle of the neck.

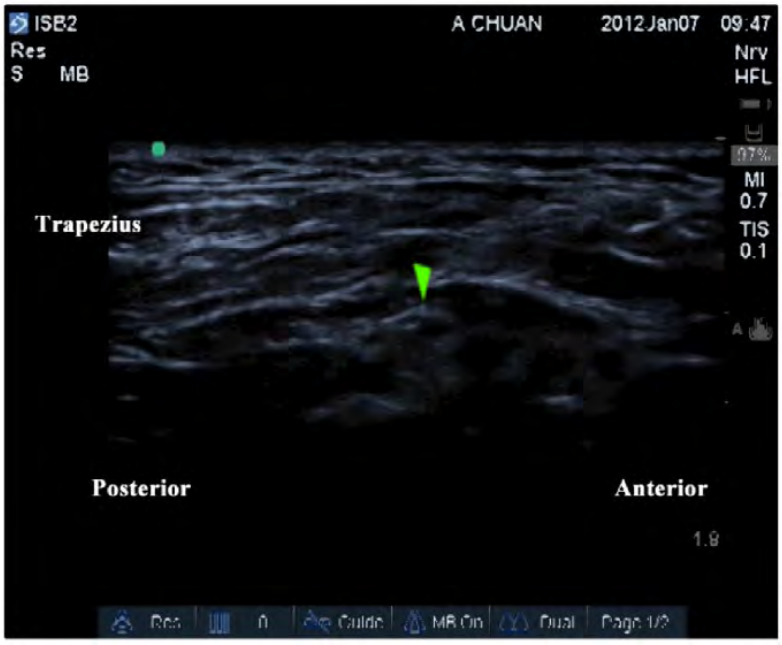


Figure 8. Still frame from a video loop, showing origin of suprascapular nerve (green arrow) branching off the upper trunk and travelling laterally and posteriorly deep to trapezius muscle.

3.2 Dorsal Scapular nerve

The dorsal scapular nerve supplies the rhomboids and levator scapula muscles. It originates from the C5 root, high in the interscalene region, and travels through scalenus medius posteriorly and inferiorly. It is often visible as a hyperechoic nerve within this muscle belly, and care taken not to damage the nerve during a posterior in-plane approach to the interscalene brachial plexus.

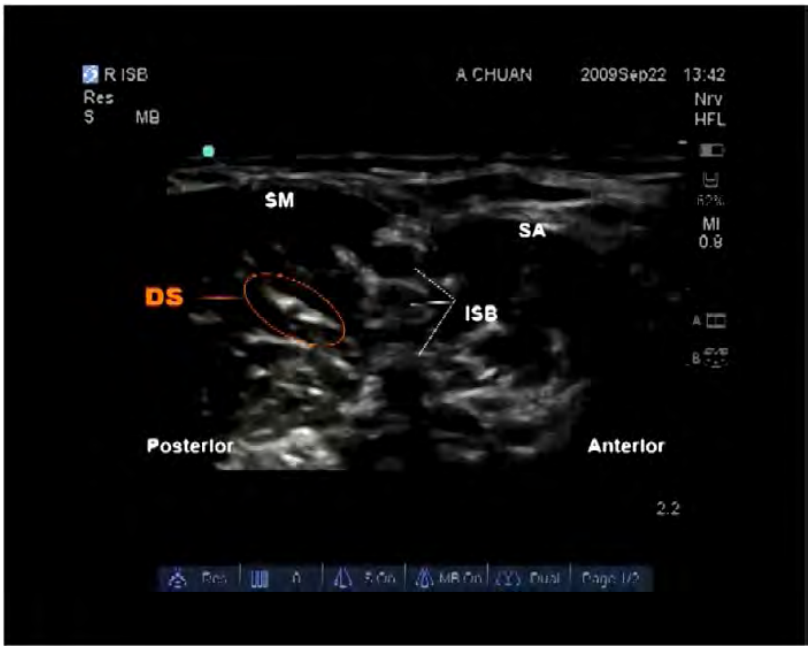


Figure 9. SAX view of the interscalene brachial plexus (ISB), between the scalenus medius (SM) and scalenus anterior (SA) muscles. The prominent dorsal scapular (DS) nerve is visible in the body of SM.

3.3 Phrenic nerve

The phrenic nerve is derived from fibres from C3 to C5 (predominantly C4), but while it is normally not part of the brachial plexus, it is usually visible in the same ultrasound planes typically used for an interscalene nerve block. In the posterior triangle of the neck, the phrenic nerve lies on the anterior surface of the scalenus anterior muscle, and runs medially across it towards the thoracic inlet. It thus lies under sternocleidomastoid muscle, and can be inadvertently blocked by local anaesthetic that diffuses out of the interscalene groove out into the prevertebral fascia. Use of targeted, low volumes of local anaesthesia in association with ultrasound guidance should thus limit the incidence of phrenic nerve palsy [6].

However variations of origin are well described and include the nerve supply derived entirely from the brachial plexus, or the presence of an accessory phrenic nerve that arises from the upper trunk, which may explain some cases of phrenic palsy even with supraclavicular blocks [7].

Identification of the phrenic nerve is often best done at a high interscalene level, when the nerve usually is visible on the superficial surface of the scalenus anterior muscle. In 70% of volunteers, a small ascending cervical artery also accompanies the nerve as it courses from lateral to medial caudad, and assists in finding the nerve [8].

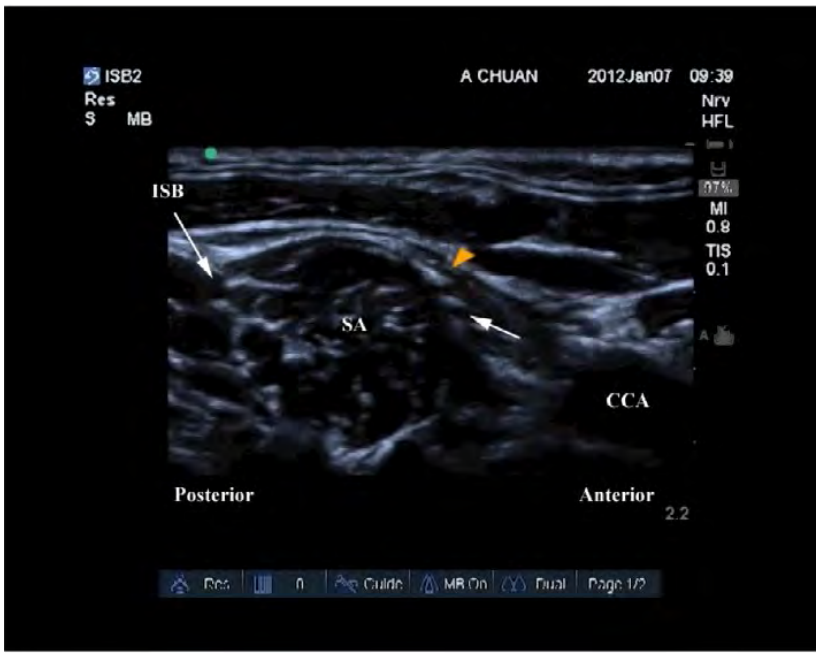


Figure 10. The phrenic nerve (orange arrowhead) is visible as a small hyperechoic structure on the surface of the scalenus anterior (SA) muscle. The white arrow points to the ascending cervical artery. The trunks of the interscalene brachial plexus are visible in the groove.

4. Vascular Anatomy in the Neck

The neck contains multiple arteries and veins that are closely associated, and not infrequently bisect through, the brachial plexus. The presence of this rich vasculature arising primarily from the subclavian artery and vein, cannot be fully appreciable using palpation and neurostimulation techniques; employing ultrasound to identify these structures will assist in minimising intravenous injections during block performance.

Descriptions of the vascular anatomy are also confounded by more variability (as well as non-unified naming conventions) than in nerves. Figure 11 below shows the complex configurations possible for vessels arising from the subclavian artery.

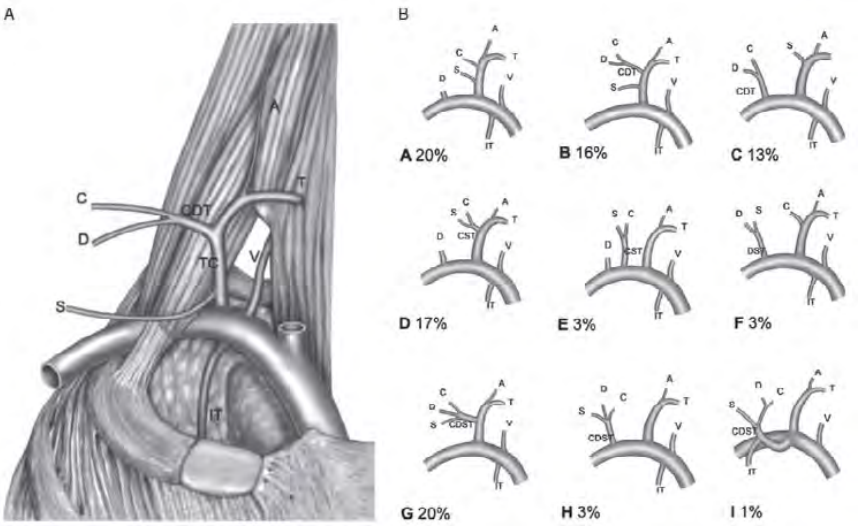


Figure 11. Diagram showing different patterns of vessels [9] in the posterior triangle of the neck. The key below relates to diagram A on the left. Relative frequencies of configurations in percentages derived from 498 cadaveric dissections, in diagram B on right.

C = Superficial cervical artery, D = Dorsal scapular artery, CDT = Common arterial trunk

TC = Thyrocervical trunk, S = Suprascapular artery, A = Ascending cervical artery

T = Inferior thyroid artery, V = Vertebral artery, IT = Internal thoracic artery

4.1 Superficial Cervical Artery

This artery is most likely to be involved with the brachial plexus at the interscalene region. Its origin is highly variable; it usually arises from a shared trunk with the suprascapular artery or other named branches.

It lies between the scalene muscles and deep to the sternocleidomastoid, and may completely overlie the brachial plexus. Identifying this vessel will allow a change of the intended needle trajectory for either an in-plane or out of plane needle approach.

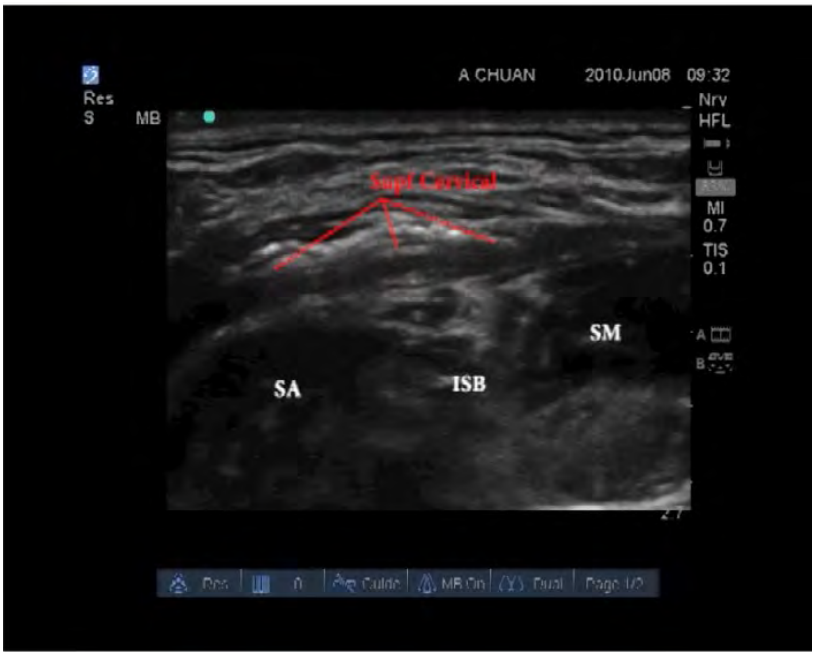


Figure 12. This still frame from a video loop shows the superficial cervical artery running horizontally across the anterior surfaces of the scalene muscles (SA and SM) and above the interscalene plexus (ISB) groove. This frame is taken from the same loop as Figure 7 above.

4.2 Dorsal Scapular Artery

This artery is most likely to be involved with the brachial plexus at the supraclavicular region. It usually arises directly from the 2nd or 3rd parts of the subclavian artery (67%), in which case it is then highly likely (90%) that it will pass through the supraclavicular brachial plexus. The incidence of this variant is about 75% of cadaveric specimens [9].

Other common variants include branching off a common thyrocervical trunk; another branch of this trunk is the transverse cervical artery, which may instead run superficially over the supraclavicular brachial plexus. If present, any of these configurations will mean a change in technique (either blockade at a different site, or choosing a different trajectory of needle approach) to avoid intravascular puncture.

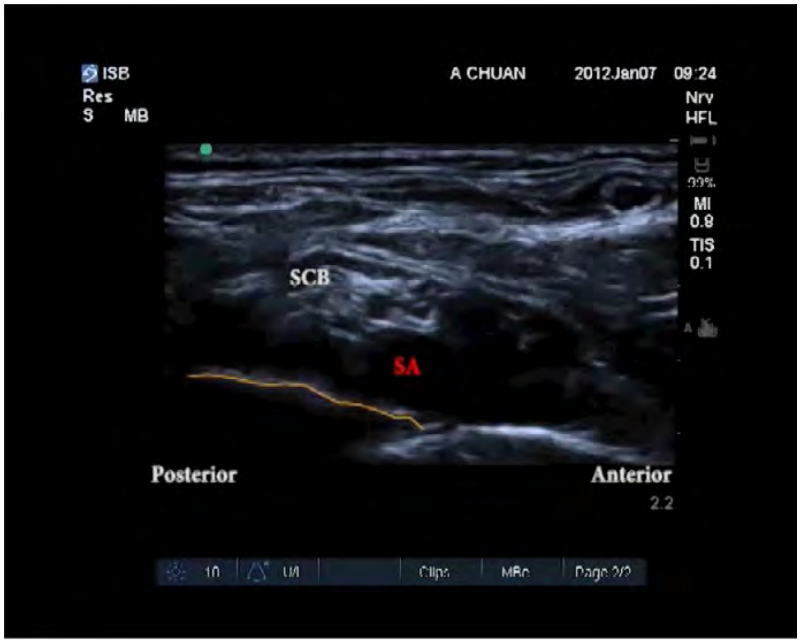


Figure 13. SAX image of the supraclavicular brachial plexus (SCB), showing the posterio-lateral position of the plexus relative the subclavian artery (SA) lying on the 1st rib.

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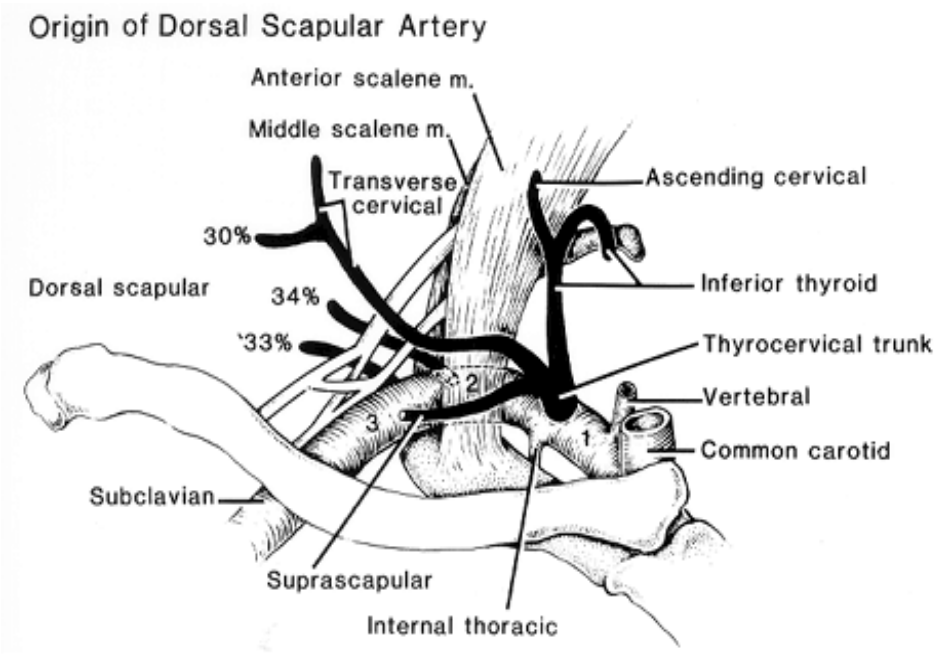

Figure 14. Relative frequencies of the origin of the dorsalscapular artery [10]

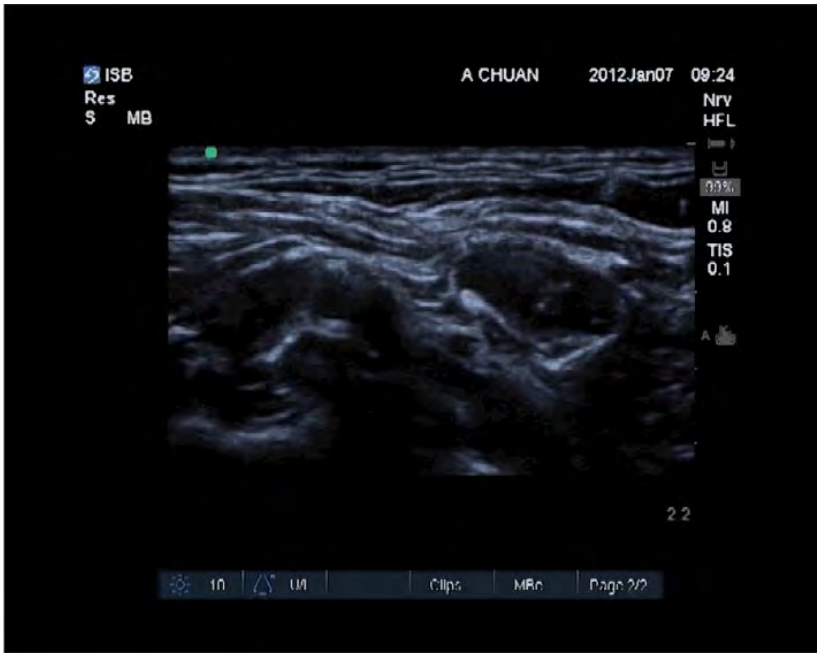

Figure 15. Still image from a video loop scanning slightly cephalad from the above Figure, showing the presence of the dorsal scapular artery arising directly from the subclavian artery, and bisecting through the brachial plexus.

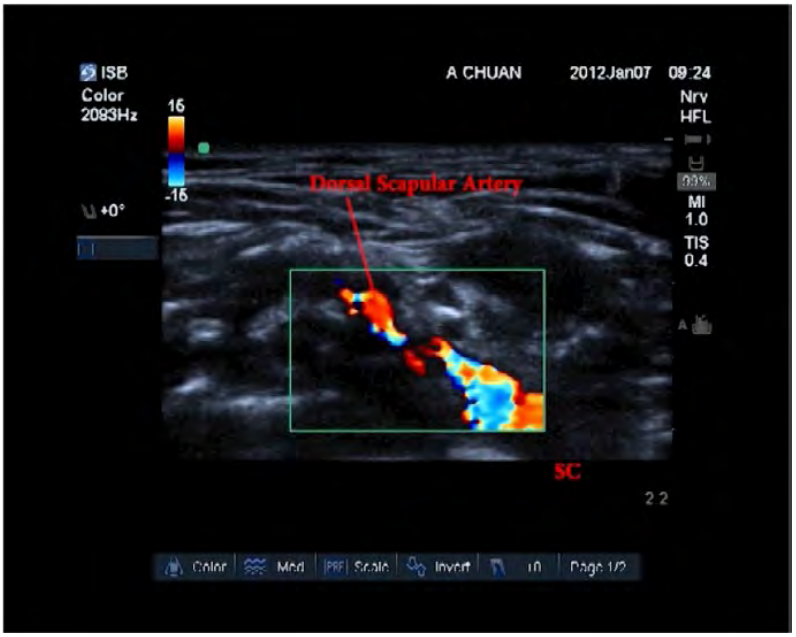

Figure 16. Same patient as above, with Colour Flow Doppler over the dorsal scapular artery.

4.3 Vertebral Artery

The two vertebral arteries arise from the subclavian on each side, and run cephalad between the scalenus anterior and longus colli muscles, adjacent to the cervical vertebrae and the sympathetic trunk. In 90% of patients, the vertebral artery then enters the transverse foramen of C6 (variability at either C5 or C7) and travels within the transverse foramina up to C2. It then describes a loop to allow it to pass through the transverse foramen of C1 before running horizontally posteriorly and finally into the vertebral canal to form the basilar artery.

5. Detecting Anatomical Variations during Pre-scans

Given the high degree of variability of both nerve and vascular structures in the neck, it is prudent to perform a pre-scan using ultrasound. This will determine the anatomical relationships and assist in forming a decision on the needle insertion point and subsequent trajectory to perform the block. This minimises the risk of complications and increases efficacy of the block.

5.1 Pre-scan Checklist

My technique prior to doing brachial plexus blocks above the clavicle is to initially perform a 2D scan at a reasonable depth using a high frequency linear array probe. I would commence at the site of block, and then do a scan for:

- neural structures, paying attention to variants and small nerves coming off the plexus
- trace back technique where I scan both distal and proximal from these nerves, paying attention to their course and relationships
- if necessary, this trace back may be as proximal as identifying each nerve root as it emerges from the cervical intervertebral foramen
- vascular structures, paying attention if vessels bisect the plexus, or are in the path of the needle
- if necessary, colour flow Doppler (CFD) and/or colour power Doppler (CPD) is employed to discriminate between vessels and nerves
- very small calibre vessels or low pressure vessels may not appear even with CFD/CPD. Sometimes a steady 2D view will show the pulsations of the vessel to the naked eye
- beware that inadequate pressure and excessive pressure of the probe on the skin may change the calibre of vessels disproportionately

5.2 Identifying Correct Cervical Levels

Particularly for interscalene blocks, it may be necessary to trace back the neural structures to their cervical levels. Identifying the cervical levels is also important for median nerve blocks, cervical nerve blocks, and with a slight adjustment, for facet blocks.

Each cervical vertebral transverse process is easily seen as a drop out shadow on ultrasound. The shadow it creates looks like a fish mouth, and the nerve root that emerges looks like a small pearl that the fish is swallowing (allowing for some poetic license).

Also, the transverse processes of cervical vertebrae have distinctive features that allow discrimination using ultrasound, with peaks corresponding to the anterior and posterior tubercles of the transverse process.

The C7 anterior tubercle is absent, and the vertebral artery is found anterior to the nerve root. CFD may be used to identify the vertebral artery if necessary; care must be taken not to confuse the large vertebral artery with the cervical/radicular arteries that are closely associated with the nerve root when it emerges from the intervertebral foramen. These smaller arteries form a network supplying the nerve and contribute to the anterior spinal artery within the vertebral canal.

The C6 transverse process is most prominent, with relatively large anterior and posterior tubercles.

With more cephalad cervical vertebrae, the tubercles are equally prominent. The vertebral artery may be seen when the scanning plane of the ultrasound transducer is at an intervertebral level.

In these series of still frames from a video loop, the nerve roots from C4 to C8 are scanned from cephalad to caudad.

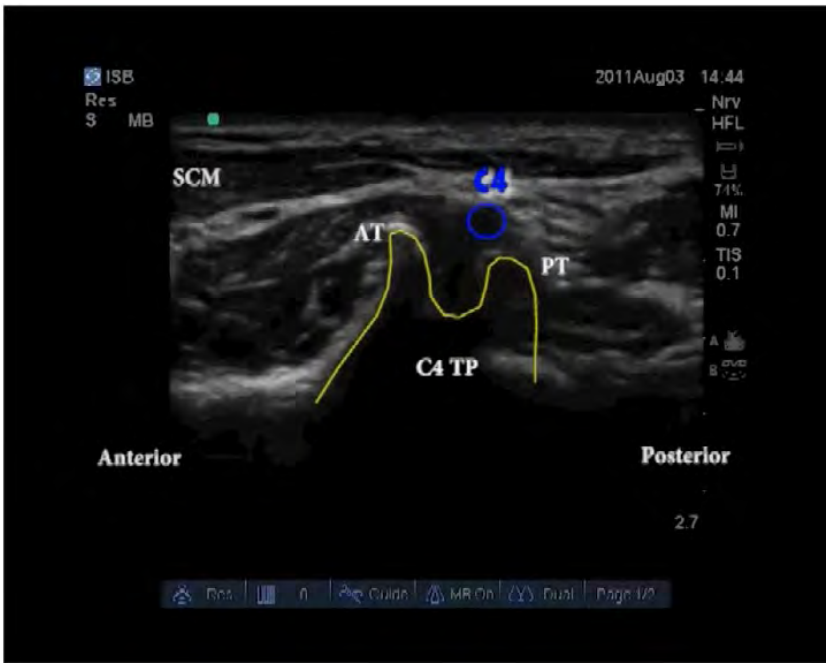

Figure 17. SAX view at the C4 transverse process (TP), as the nerve root emerges from the intervertebral foramen. Anterior tubercle (AT), posterior tubercle (PT).

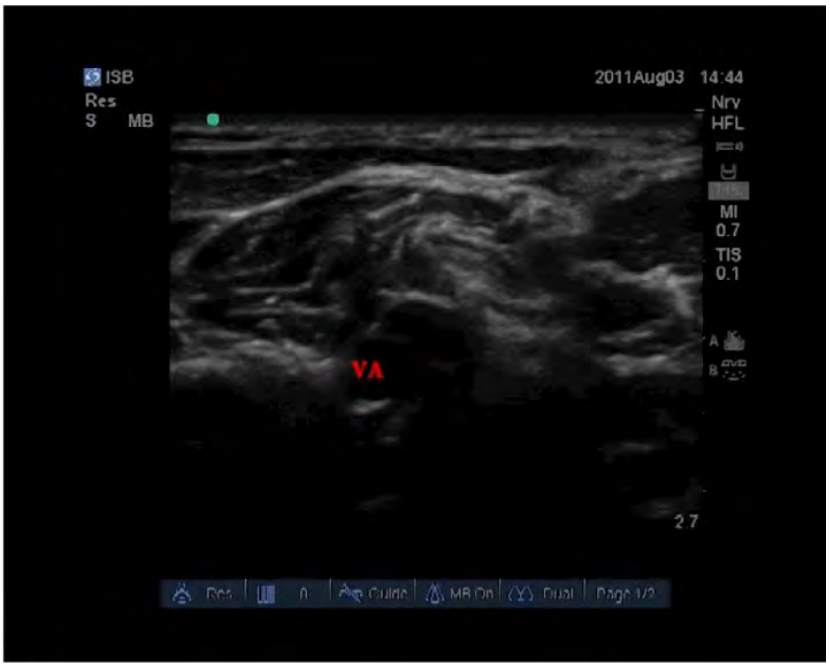

Figure 18. Vertebral artery (VA) visible between C4 and C5.

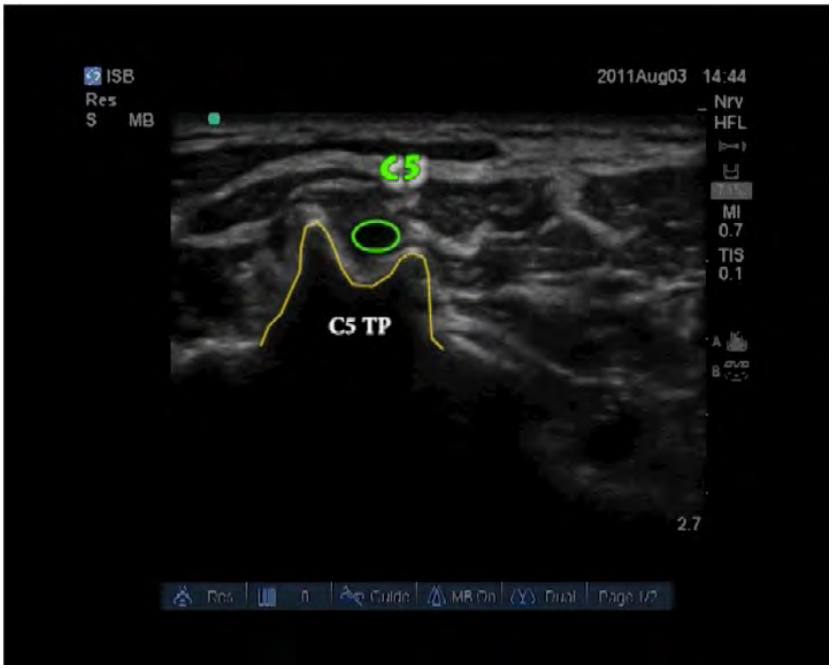

Figure 19. C5 nerve root emerges. Note the relative sizes of the tubercles.

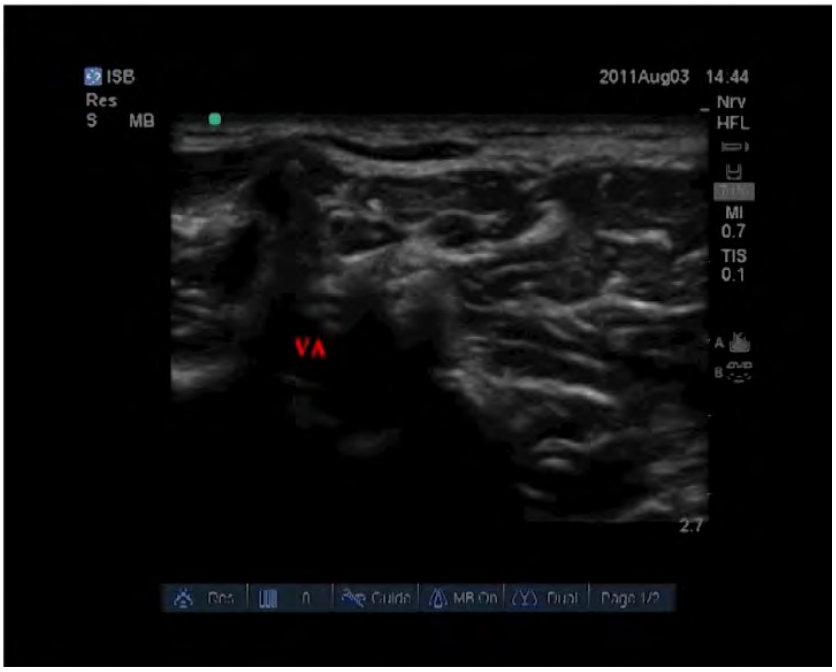

Figure 20. Vertebral artery visible between C5 and C6.

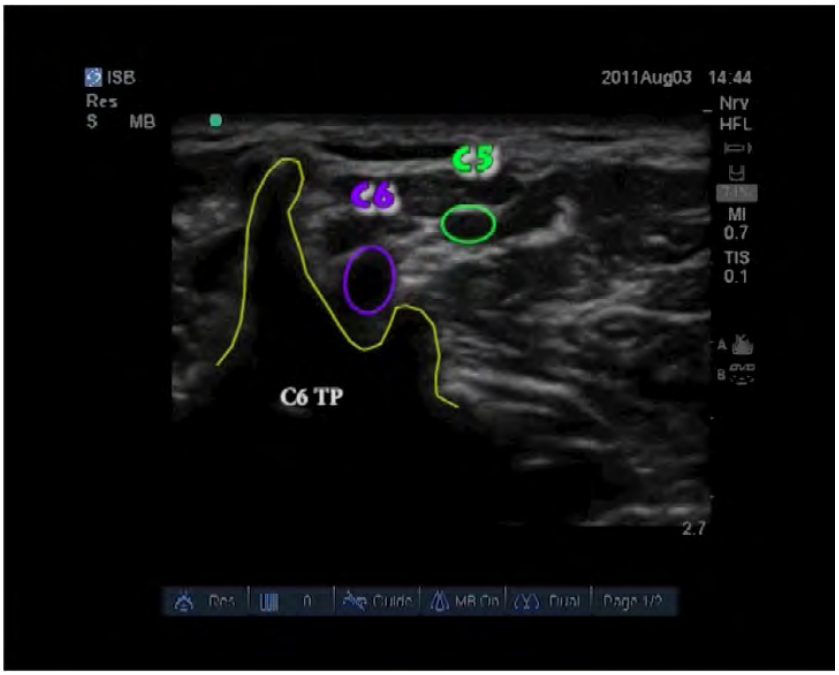

Figure 21. Large prominent tubercles of C6 forming a large transverse process

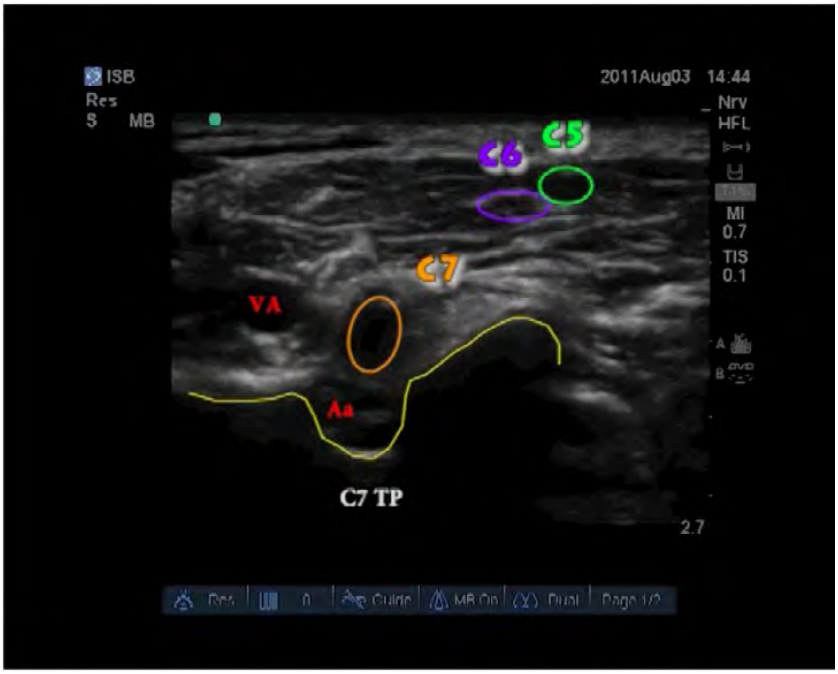

Figure 22. Large vertebral artery anterior to the C7 nerve root. Smaller arteries visible next to the nerve root. The C7 transverse process is not as prominent as C6.

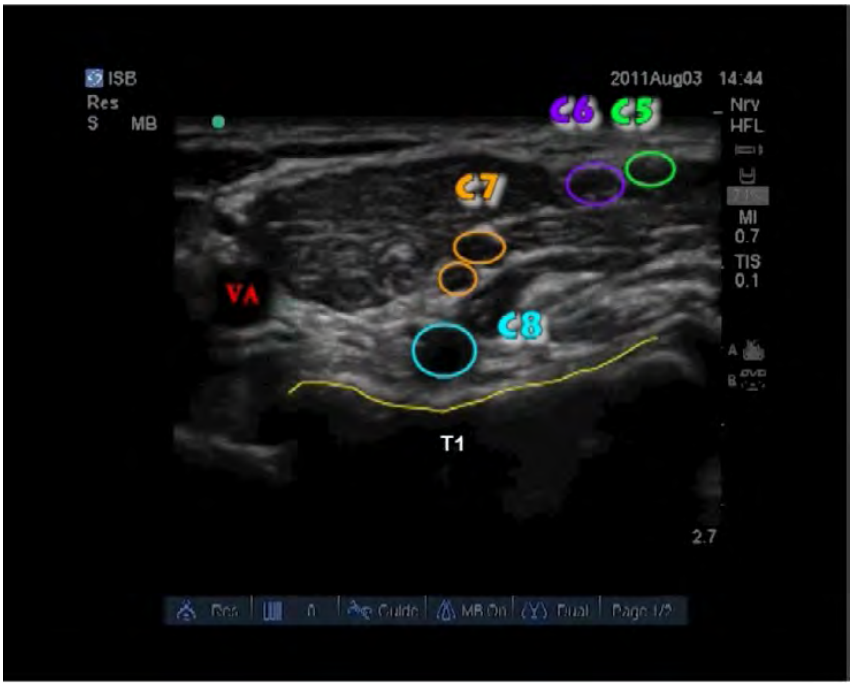

Figure 23. C8 nerve root emerges from the intervertebral foramen. Note each nerve root joining the others to form the plexus.

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Making abdominal blocks work

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There are a number of challenges in using abdominal wall blocks

Patient variables

1. Varying ultrasound appearance of abdominal wall structures
2. Variable anatomy of nerves
3. Complexity of innervation
4. Effects of obesity, air in tissues, dressings, wounds

Specific challenges

1. Extensive wounds
2. Off midline wounds
3. Surgery under blocks alone

Anatomy

Understanding the location and distribution of the nerves is as critical for abdominal block as for other peripheral block procedures. The 3 lateral muscles of the abdominal wall [external oblique (EO), internal oblique (EO) and transversus abdominis (TA)] are most readily imaged at around 45 degrees from the midline between the costal margin and the iliac crest. All 3 muscles become aponeurotic as they pass towards the midline with the EO and IO aponeuroses forming the rectus sheath around the medially situated rectus abdominis muscle (RA). The fleshy border of EO and IO demonstrates a variable overlap of one and the other. Although TA also becomes aponeurotic as it passes medially there is a portion of TA that lies deep to the rectus muscle and posterior rectus sheath where the rectus passes over the costal margin. The rectus muscles are readily identified near the midline anteriorly where they form a symmetrical appearance in transverse scanning. The posterior rectus sheath is characteristically imaged as 2 distinct layers almost in contact with each other.

Any of the abdominal wall muscles, particularly the rectus may be affected by **denervation** associated with previous surgery. This causes the muscle to become thinner and whiter (fibrotic) under ultrasound imaging. **Age related changes** are also seen in imaging the muscles, old age usually increases echo reflectiveness possibly by causing muscle fibrosis. **Obesity** increases the thickness of the adipose layers found both external and internal to the muscles. There is no adipose tissue between the muscle layers. The superficial Scarpa's fascial layer becomes thickened with adipose tissue and may resemble a muscle layer.

Figure 1. Thickened Scarpa's fascia.

The nerves of the abdominal wall may be thought of as an extensive plexus, there are many communications between adjacent nerves and they also communicate via a plexus accompanying the deep circumflex iliac artery which ascends in the lateral abdominal wall and the inferior and superior epigastric arteries in the substance of the RA muscle. These anastomotic connections and the possible entry of sympathetic nerves at the origin of these vessels may explain the relative difficulty in obtaining full anaesthesia using local anaesthetic in the transversus abdominis plane (TAP). In addition according to unpublished observations by the author unilateral TAP block does not extend fully to the midline suggesting some cross-over of nerves.

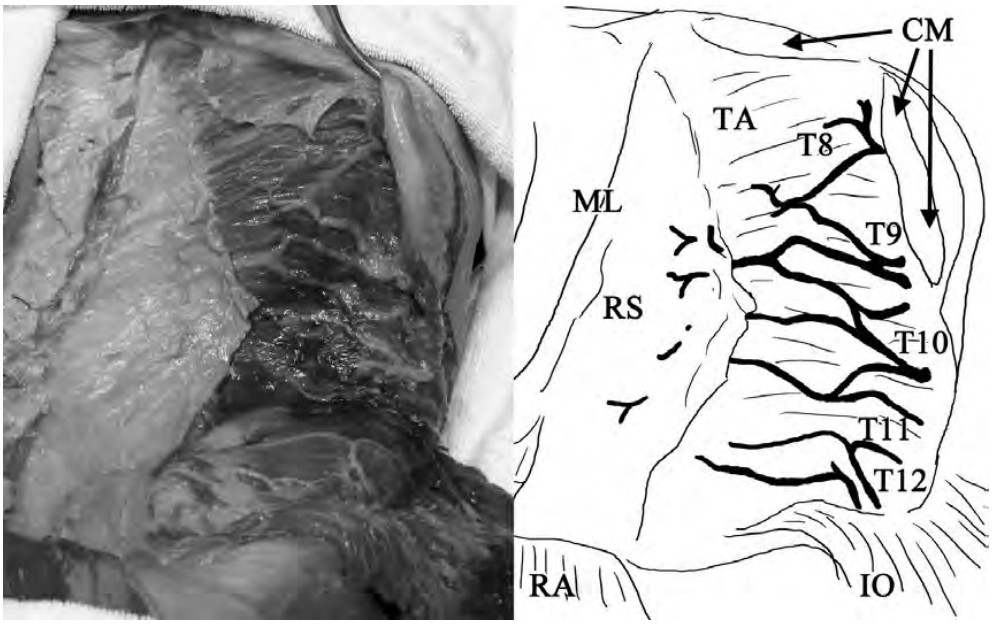

Figure 2. & 3. Dissection and diagram showing anastomotic connections between nerves T8 to T12 in the subcostal area. Costal margin CM, midline ML, rectus sheath RS, rectus abdominis RA, internal oblique IO, transversus abdominis TA. From Barrington, M. J., Ivanusic, J.J., Rozen, W. M., Hebbard, P. (2009). "Spread of injectate after ultrasound-guided subcostal transversus abdominis plane block: a cadaveric study." Anaesthesia 64(7): 745-750.

Each segmental nerve supplying the abdominal wall (T6 to L1) enters the TAP at the end of the corresponding rib passing deep to any costal cartilage. Prior to this a lateral branch is given off near the angle of the rib (in a more posterior position than indicated in most texts). This **lateral branch** emerges through the muscles, supplying the external oblique from the

point of penetration of the muscle, to emerge subcutaneously around the mid-axillary line where it gives anterior and posterior branches. The anterior portion of this nerve supplies skin to about the mid-clavicular line while the **long branches within external oblique** can be traced **into the aponeurotic section** of that muscle antero-medially (including the portion incised in inguinal hernia repair).

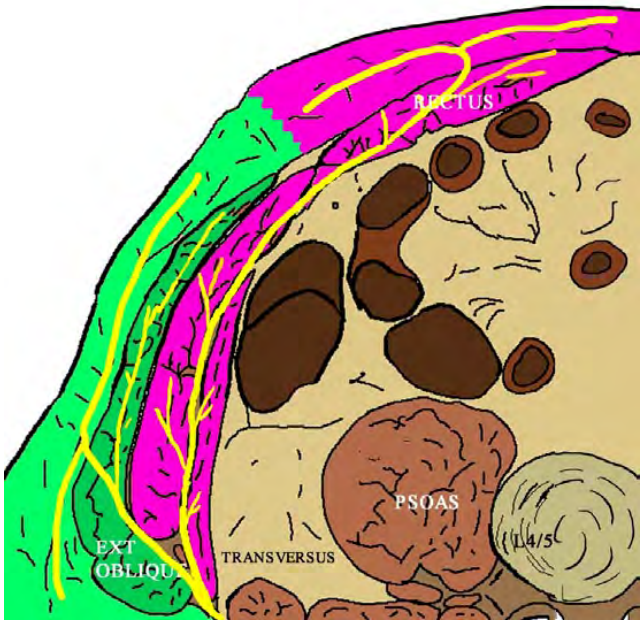

Figure 4. Schematic of the distribution of innervation of the abdominal wall. The external oblique muscle is supplied by long intramuscular nerves derived from the lateral branch of the segmental nerves

From within the TAP the main (anterior) branch supplies the adjacent muscles (TA and IO) as it passes with multiple fine nerves passing into the muscles from the TAP. The lower nerves (T9 to T12) penetrate the rectus sheath from posteriorly to pass behind RA before penetrating through to supply RA and the overlying skin. The lowermost of these nerves typically have a shorter or even absent course behind the rectus muscle. **The L1 nerves** (ilio-inguinal and ilio-hypogastric) pass into the abdominal wall anterior to the quadratus lumborum muscle and then course deep to the TA muscle. They penetrate through TA and **are not found in the TAP until a more anterior position** than the lower intercostal nerves. They then pass superficially once medial to the anterior superior iliac spine (ASIS) to penetrate the internal oblique and pass anterior to the RA. The upper nerves (T6 to T8) emerge beneath the costal cartilages from where they may penetrate through the rectus sheath into the substance of the rectus muscle after a short course. More commonly they pass for a few cm either deep or superficial to the rectus sheath before penetrating into rectus.

The **variations in anatomy of most clinical importance** are **the variability in the passage of nerves between RA and the posterior rectus sheath** and the **variability in the position of the L1 nerves.**

Successful abdominal wall block has a detectable upper, lower and lateral boundary of block to cold sensation. For analgesia midline incisions are the most straightforward as it is only necessary to cover the area of nerve supply to the wound, which is supplied by the anterior branches. Bilateral block in the TAP extending over the wound area will therefore produce wound analgesia. Intra-abdominal structures are probably not covered by this technique and multi-modal analgesia including opioids is required.

Ensuring **adequate spread of local anaesthetic** is important to coverage of abdominal blocks. There is considerable inter-individual difference in the ease of spread of solution within the TAP. It has not been investigated whether this can be predicted based on patient factors or is more dependent on injection technique. My impression is that spread is better in young patients particularly children, and generally better in the upper abdomen compared to near the iliac crest. One injection of 20ml into one place in an adult will generally cover 10 to 15cm in the midline or 3 vertebral segments. If the needle is moved (hydro-dissected) across the direction of the nerves it is possible to **create more extensive block with the same volume**.

The **sub-costal oblique line**, along the costal margin and then across to near the ASIS is the neural plane for the anterior branches of the segmental nerves. Blockade along this line is adequate for midline incisions. **Extensive incisions** require extensive spread of block that is best produced by the hydro-dissection of local anaesthetic across the direction of the nerves. Catheters may be successfully placed along the sub-costal oblique line for subsequent infusion or bolus regimes.

For **incisions lateral to the rectus abdominis** muscle the muscular and sometimes cutaneous innervation of the **lateral branches contribute to wound pain**. The position of the nerves within the respective muscle and subcutaneous tissue remains to be elucidated. One approach is to infiltrate these tissues widely with dilute local anaesthetic using ultrasound imaging to ensure spread within the target area. Although local anaesthetic is known to have dose dependent myotoxicity, the damage in animal studies is reversible and there is a paucity of adverse effects reported from intramuscular local anaesthetic despite over 100 years of accidental and deliberate injection.

Inguinal hernia repair will only be partly covered by TAP block alone as the **external oblique and skin are innervated by the lateral branches**, the **genito-femoral nerve** also provides innervation to the wound area. The external oblique muscle may be infiltrated with local anaesthetic and the genito-femoral nerve may be blocked separately.

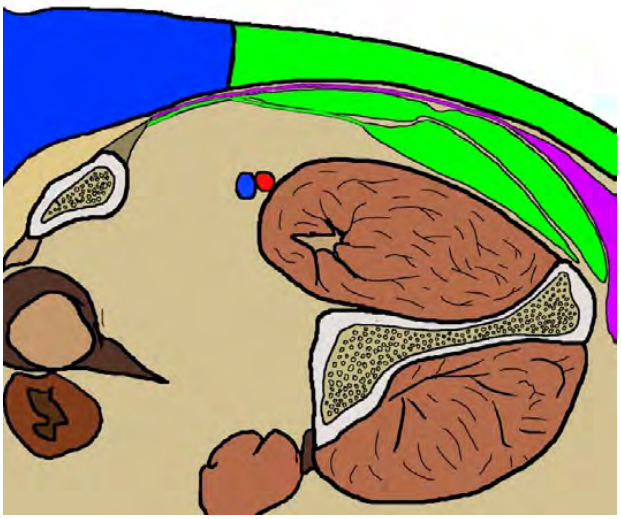

Figure 5. Diagram of transverse section along the incision for open inguinal hernia repair (left side is medial). Blue indicates the innervation of the genito-femoral nerve (skin of the medial wound), green the anterior branches of T12 and L1 (transversus abdominis, internal oblique, overlying skin) and purple the lateral branches (external oblique and it's aponeurosis)

Block of the genito-femoral nerve should be carried out proximal to the wound. A technique I favour is to place local anaesthetic in a periarterial position deep to the inguinal ligament superficial to the external iliac/common femoral artery. The local anaesthetic can pass along the sheath of the artery and into contact with the descending genito-femoral nerve on the body of the psoas muscle.

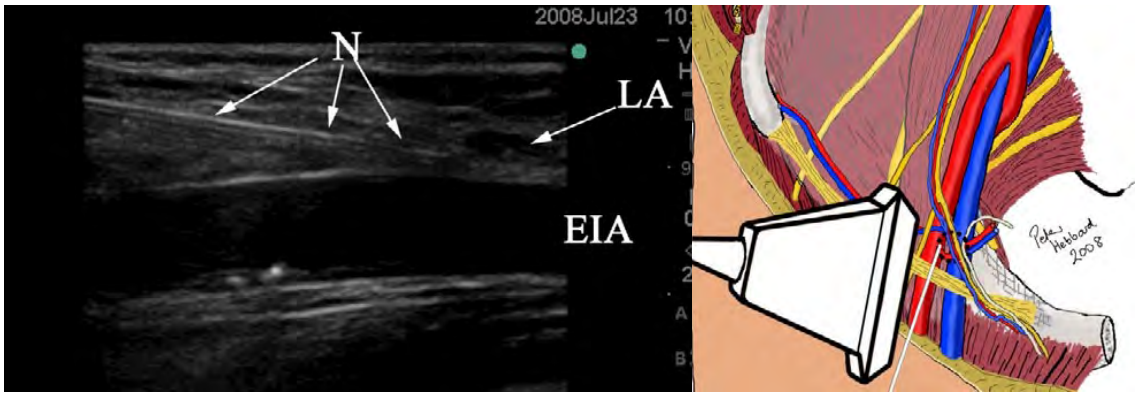

Figure 6 & 7. Perivascular block of the genito-femoral nerve. Femoral artery/external iliac artery (EIA), local anaesthetic (LA) in perivascular position, needle (N)

Surgery under blocks

Performing surgery under abdominal blocks alone is challenging. It is more difficult to produce surgical anaesthesia with blocks in the abdominal wall, possibly because of the extensive anastomosis between nerves, the ascending and descending plexus of nerves along the major arteries and possible sympathetic inflow along the vessels. An approach I have found useful involves blocking the nerves in their anatomical location for innervating the incision with relatively concentrated local anaesthetic e.g. ropivacaine 0.5% making sure that the local anaesthetic is hydro-dissected widely across the course of the nerves. The area of skin incision is then supplemented with subcutaneous local anaesthetic. Another source of pain during the operation may include an intra-abdominal organ or omentum protruding through a hernia, which will not be covered by the peripheral block. In addition the innervation of the peritoneum is not described in the texts although it is most likely innervated via the anterior branches of the segmental nerves.

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Peter Hebbard January 2012

ultrasound guided regional anaesthesia in hostile environments

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In the military medical environment, regional anaesthesia has characteristics that make this anaesthetic particularly 'field friendly' for both anaesthesia and analgesia [1]. Advantages of regional anaesthesia include:

- Excellent operating conditions
- Profound perioperative analgesia
- Stable haemodynamics
- Limb specific anaesthesia
- Reduced need for other analgesics (opioids)
- Improved post-operative alertness
- Reduced post-operative nausea and vomiting
- Rapid recovery from anaesthesia
- Improved sleep and rehabilitation
- Preservation of protective airway reflexes
- Minimal side effects
- Reduced complications
- Simple, easily transported equipment needed

Regional anaesthesia facilitates evacuation of alert patients, free of pain and nausea, who can be active proponents in their own recovery. This is a tremendous advantage in austere environments where limited personnel and supply resources can then be freed for service on more acutely ill patients. With the first evacuation of a United States casualty using a continuous peripheral nerve block (CPNB) in 2003, the utility of regional anaesthesia for the management of pain in the modern evacuation system was clear [2]. Unfortunately, the nature of trauma management often precluded early placement of CPNB catheters until after resuscitation and initial stabilisation surgery. Additionally, catheter placement with nerve stimulation technology usually necessitated an alert casualty who could provide feedback warning of possible nerve injury. Since wounded warriors were often experiencing significant pain during stimulation blocks, these procedures were technically challenging and often only available when regional anaesthesia consultants were deployed. Ultrasound guidance of regional anaesthesia blocks not only eliminates many of these challenges but allows anaesthetists to develop a comprehensive perioperative pain management plan that includes CPNB, prior to patient emergence from trauma surgery.

Beyond pain management, the addition of ultrasound technology to the combat support hospital has revolutionised diagnosis and treatment for battlefield trauma. Portable ultrasound has become the field medical imaging system of choice for 21st century conflicts. The FAST

exam (Focused Assessment with Sonography for Trauma) allows for rapid assessment of haemothorax, pneumothorax, haemoperitoneum, and intravascular filling status [3]. Ultrasound also provides a means to obtain venous or arterial access in patients who may be hypovolaemic and difficult to cannulate. The device has also proven useful for fracture diagnosis and foreign body location.

From April – July, 2009, the US Army established the first Role 3 (Combat Support Hospital - CSH) Acute Pain Service (APS) with the British lead coalition hospital at Camp Bastion, Helmand Province, Afghanistan. During the deployment of the U.S. Army APS, the Camp Bastion CHS performed approximately 455 surgical cases (5.62 daily). The APS was consulted for pain management of many combat casualties. Wounds tended to be wide-ranging from high-energy weapons including improvised explosive devices, high velocity firearms, and rocket propelled grenades resulting in extensive damage to musculoskeletal, nerve, and vascular structures. The APS was primarily responsible for developing pain management plans for wounded prior to evacuation to Selly Oak NHS Hospital, Birmingham, England (UK wounded) or Landstuhl Regional Medical Center, Landstuhl, Germany (US wounded). Of the 160 injured soldiers managed by the APS, 61.8% (n=99) underwent ultrasound guided regional Anaesthesia. Most of the blocks were continuous peripheral nerve blocks. The distribution of blocks is provided in Fig. 1.

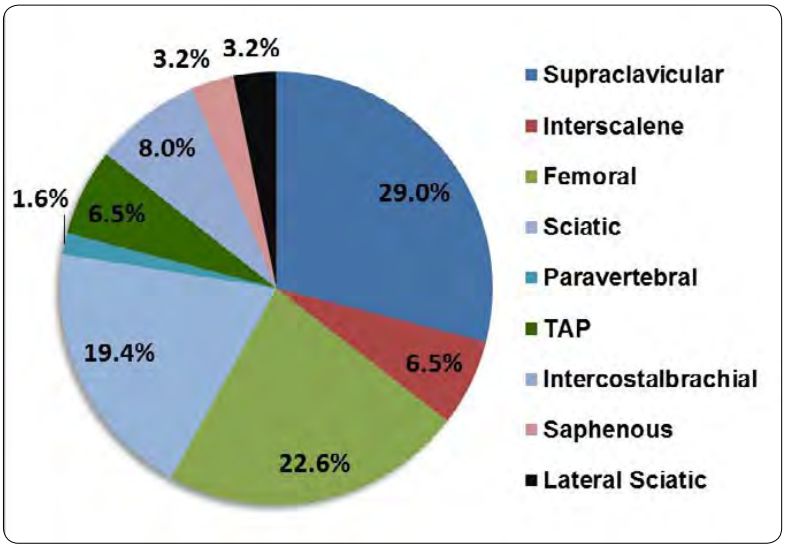

Fig 1. Frequencies for the types of regional anaesthesia/analgesia techniques performed by the APS on 51 (71.8%) of injured soldiers. TAP = Transversus Abdominis Plane (TAP) block

Of these 50 were accomplished following initial surgical stabilisation while the patient was still under general anaesthesia. The advantage of being able to visualise the regional needle in real-time with target nerves and surrounding tissues greatly enhanced the value of continuous nerve block in the management of many trauma patients. It was possible in many patients to promise the warrior complete relief from their trauma pain prior to initial induction. This ability is extremely valuable for maintaining morale in wounded warriors and their comrades.

The addition of the APS with ultrasound capability significantly improved pain management during this pilot program. Average percent improvement in pain relief scores from recall prior to arriving at the CSH to air evacuation was 51.9% ± 31.2. A summary of this experience is provided in Fig. 2. There were no complications related to the regional anaesthetic in this cohort of patients.

Figure 2. Summary of Camp Bastion, Acute Pain Service Experience.

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ultrasound and regional anaesthesia in private practice

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Convincing private hospitals to invest in ultrasound machines for use in theatre suite takes organisation and persistence. There is strength in numbers, so it is best to organise your colleagues. A united front is more difficult for Hospital administrators to ignore. Approach medical advisory committees with arguments centred around patient safety and the broad utility of ultrasound (US) machines in the theatre. The case can be made that the US machine is not just for blocks, but is necessary for vascular access, cardiac assessment, trauma assessment, and use by surgical teams (vascular, breast, urology, hepatobiliary, O&G). Do not forget local volunteer organisations who might be interested in donating to your worthy cause.

With ultrasound machine purchase there are many features that need to be considered. The style of the machine is important (e.g. cart based, portable or wall mounted), which determines size, weight, footprint, stands, and manoeuvrability. In addition, ease of use, boot up time, image quality, still and video clip storage, and download ability should be considered. Type of probes (shape, frequency and number) is important to meet your clinical requirements and budget. Optional features include software for colour Doppler and cardiac packages for transthoracic echocardiography and transeosophageal echo. Warranties vary from 1 to 5 years and service back up and software upgrades are also worth investigating. Care and maintenance plan of machines must be considered.

Block sterility (no touch technique or full asepsis) should be carefully thought out, along with infection control guidelines concerning cleaning of probes after use. Hospital and federal guidelines need to be considered.

Developing one's own personal skills requires access to both machines and patients requiring intervention. I advise practitioners to make a concerted effort over a defined period of time. Skills can be developed from meetings and workshops (ASURA, ARACUS, Hong Kong International Symposium on Spine and Paravertebral Sonography, ASRA, ISRA , ESRA), courses and diplomas (University of Melbourne) internet, journals (RAPM), text books and colleagues, and do not forget your friendly medical imaging firm.

One should practice aseptic techniques, keep detailed contemporaneous clinical notes, consider recording stills or clips, and audit your practice. Reviewing patients will help your practice evolve and improve.

Introducing ultrasound into you clinical practice requires sympathetic and understanding surgical colleagues. The best approach is to engage, involve and educate them, and endeavour to keep them on your side. I occasionally remind surgeons that I use ultrasound and neural blockade not for myself, but for the benefit of their patients. One should endeavour to place blocks outside of surgical time, and strive to improve list efficiency. Good anaesthesia and pain management reflects on the quality of the surgeon's practice.

Ultrasound machine accreditation in private practice first requires a Location Specific Practice Number (LSPN) obtained from Medicare (29 pg form). Department of Health and Ageing (DHA) has instituted a Diagnostic Imaging Services (DIS) accreditation programme. Stage 2

accreditation is to be completed by June 30th 2012. There are 5 pathways to accreditation with 3 approved accreditors (www.diagnosticimaging.health.gov.au). Costs $1500 plus a lot of time.

Currently Medicare billing revolves around the number 55054 in the DIS section of the MBS. To be eligible the imaging service has to be clinically relevant, provided by a medical practitioner (or a person under supervision of) with a written report. The bill must be annotated 'SD' for Self Determined referral, with a time of day recorded.

In 2009 the DHA proposed 4 new item numbers incorporating US with vascular access and neural blockade. The Australian Society of Anaesthetists was accepting of this proposal. In Dec 2010 the DHA abandoned their own proposal and unilaterally decided to rescind the use of 55054 by anaesthetists. Other practitioners may still bill 55054. Billings by anaesthetists in year '09-'10 was $AUD1.8 million, and represented 8% of expenditure of 55054. Uncertainty surrounds the timing of the withdrawal of this number, but major updates of the MBS occur on May 1st, so it could be then.

The ASA have applied to Medical Services Advisory Committee (MSAC) for MBS allocation of two new items, ultrasound associated with vascular access and neural blockade. This application was placed in 2011, and will take a minimum of two years. These new items will fall in the anaesthetic section of the MBS, outside of DIS, and therefore do not require accreditation. The ASA approached the Minister of Health requesting 55054 funding for anaesthetists be continued whilst the new MBS item allocation ratified. The Minister flatly refused.

With this new MBS item number application, MSAC want evidence that ultrasound is clinically useful and better than existing technologies, and represents a cost benefit. By contrast the Government has invested $AUD250 million in video consults, with no evidence of any benefit.

The recommended time to commence Stage 2 DIS Accreditation is Feb 2012 to allow completion by Jun 30th. The obvious dilemma then is whether anaesthetists go down the path of Stage 2 Accreditation, incurring considerable cost and time burden, with the possibility of the billing of 55054 being rescind on May 1st, thereby rendering the whole process superfluous.

ultra-long term nerve infusions

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The first continuous peripheral nerve block (CPNB) placed in a wounded American soldier occurred on October 3rd, 2003, at the 21st Combat Support Hospital (CSH) in Iraq [1]. A 21-year-old (185 cm, 84 kg) previously healthy man sustained an injury to his left calf from shrapnel from a rocket-propelled grenade (Fig. 1). Neurologic evaluation revealed loss of motor and sensory function in the distribution of the left tibial nerve. Despite 18 mg of intravenous morphine sulfate, administered over 1 hour, the patient continued to complain of persistent 10 out of 10 pain. In consultation with the orthopaedic surgeon, the patient was offered CPNB catheters for pain management. Prior to his trauma surgery, the patient was sedated and a lumbar plexus and posterior sciatic continuous peripheral nerve block was placed with nerve stimulator guidance. The block procedure took 20 minutes. The patient was conversant during the block and had pain relief 3 minutes after the local anaesthetic injections. Successful neural block was documented 10 minutes after block placement by the loss of hip flexion and foot dorsiflexion. Following initial wound debridement and placement of an external fixator, the patient was alert and pain free in the CSH recovery tent. The CPNB catheters were connected to infusion pumps. The lumbar plexus and sciatic catheters were infused with 0.2% ropivacaine at 6 mL/hr and 10 mL/hr, respectively. This patient was evacuated to Landstuhl Regional Medical Center in Germany 15 hours later and required no interventions for pain during the 5-hour flight. He would go on to have 4 additional operations and 16 days of pain management with the CPNB catheters placed during his initial stabilisation surgery in Iraq.

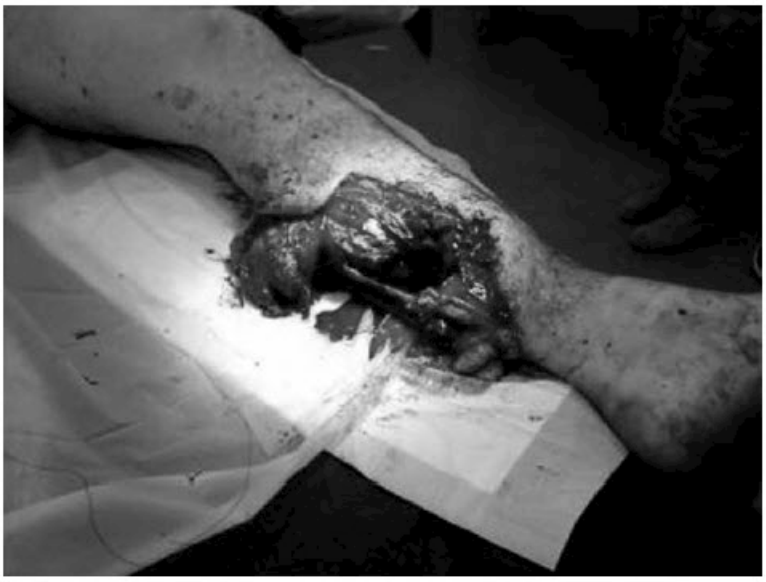

Figure 1. The patient's wound presentation on arrival at the facility

Since this first experience, CPNB has rapidly become a major management tool for hundreds of casualties with a variety of combat injuries within United States (US) military medicine. In a survey of 110 casualties arriving at Landstuhl, Germany from the wars in Iraq and Afghanistan, a comparison between casualties without CPNB (n=83), and those who did (n=27) was undertaken [2]. Patient's with CPNB catheters had less pain when asked than those casualties without (p=0.031). At Landstuhl, patients with CPNB reported 74.0±18.9%

relief compared to 61.7±24.1% without, despite higher worst pain intensity scores in the CPNB group.

In addition to the excellent pain management capability that CPNB brings to the trauma patient, this technology has a number of other significant advantages in the current evacuation environment. Since the 1860s, morphine has been the standard battlefield analgesic for the US military. While the effectiveness of opioid medications in the management of pain is beyond dispute, current evacuation system realities make reliance of this one class of medications problematic (Fig. 2).

Figure 2. Modern air evacuation environment.

Rapid evacuation of casualties to higher roles of medical capability has contributed to the lowest “died of wounds” rate in US military medical history. Unfortunately this environment is challenging medically. Patients can be stacked 4 high, the aircraft is not insulated and loud, vibration is constant, and medical monitoring equipment functions poorly during flight. Providers were less enthusiastic about pushing morphine on evacuation flights for fear of devastating side effects, such as respiratory depression. CPNB, on the other hand, offered intense, extended analgesia without any of the side effects associated with opioids. The catheters also provide a means to re-establish surgical blockade for frequent debridement procedures which is less stressful for the patient and provider. It quickly became routine within the US system to maintain CPNB catheters for as long as the trauma patient required repeated surgery.

There have been concerns about perceived conflict in the need to provide prophylactic anticoagulation and the risk of using CPNB in this setting. Studies of CPNB in patients receiving both low-molecular weight heparin or warfarin have not supported this concern [3,4]. Compartment syndrome is always a concern following battlefield limb injury. Although pain is the earliest sign of a developing compartment syndrome, failure to provide adequate pain management for fear of missing a compartment syndrome is draconian and unnecessary. Current US surgical guidance recommends early release of compartments in a traumatised

limb if the surgeon is concerned about the development of compartment syndrome during evacuation. More importantly, analgesic CPNB does not block the pain of ischaemia and usually avoids the sedation and confusion associated with opioid monotherapy. A more alert casualty, coupled with the need for CPNB follow-up by an acute pain service (APS) team actually provides enhanced warning of compartment syndrome in the author's experience.

The US military experience with long-term CPNB in the management of combat casualties has been very positive. In one series from Walter Reed Army Medical Center, 287 combat casualties underwent 634 operations using regional anesthesia, with 361 CPNBs placed [5].

The average CPNB remained in place for 9 ± 5 days in this cohort. Catheter-related complications occurred in 11.9% of casualties and were technical or minor in nature. The catheter-related infection rate was 1.9% and all were managed with catheter removal and no other intervention.

Long-term management of combat casualties with CPNB for both surgical anaesthesia and between procedure analgesia has been a safe and effective technique for the pain management of these complex trauma patients. Efforts to expand provider education and capability in this area of acute pain medicine are ongoing within the US military.

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Block rooms are the way forward in regional anaesthesia education! - Pro

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Definition: The Block room is a specific area within a theatre suite for the provision of regional anaesthesia services. Patients receive a peripheral or neuraxial block and are then handed over to their theatre anaesthesia team for monitoring and care during the surgery. It is staffed by regional anaesthesia (RA) faculty and trainees and concentrates the RA expertise for the benefit of the whole Department

I am convinced this is the direction we should be moving to facilitate RA Education and Research.

Surgical reasons

Surgeons are well aware of the benefits of regional anaesthesia but still put up resistance. Why? Because many people are too slow and it causes wasted theatre time [1]. We should not be rushed by surgeons when we are trying to give the patient the best care, and the trainee the best education. Regional anaesthesia should therefore be performed in a quiet, calm area away from the stress and time pressure of the operating theatre.

Anaesthetists want to do their own blocks!

Do we?

You are the exception. The majority cannot do blocks or cannot be bothered. In public practice, the majority of blocks are performed by trainees rather than the consultants anyway. Does it really matter whether the trainee is in theatre or a block room? Either way, you are not going to be holding the needle. You can also rotate through the block room to maintain skills. Many patients, who could have benefited from regional anaesthesia, miss out as they are looked after by a “non-regional anaesthesia” consultant. These are missed opportunities for better care and trainee education. With reduced training time and increased pressure to teach, we cannot afford to miss these opportunities.

Loss of ownership

This need not be the case unless you simply want to do the block then abdicate care to another. Most reasonable people will want to be absolutely sure their blocks are working before handing them over to a colleague. It provides the opportunity to watch blocks develop rather than doing a “quick single shot” followed by GA to save time and allow surgery to start. Most would also want to check up on patient’s progress in theatre so ownership is not lost.

Research and Audit

It is far easier to conduct audit and research when all patients undergoing RA pass through a central area. The block room allows for easier recruitment and data collection without interfering with theatre workflow. Data can be stored in one area and be readily available for follow up.

Logistical issues

These are often quoted as reasons against a block room. They simply need to be considered. A block room allows for consolidation of expensive resources. It is no longer imperative to have ultrasound machines available in every theatre. RA specialists can assist in one location rather than walking around all the theatres giving advice and assistance. Many centres use a dedicated area in PACU and share a PACU nurse. The drain on PACU resources is compensated by these patients having very short post-operative PACU stays or being able to bypass PACU altogether. The consultants can have a rotating roster in the block room. RA fellows would get more involved in the overall patient care. Patients would be identified the day before and the "Block list" generated. The day could be planned to ensure patients were called for and made ready in good time to minimise impact on theatre workflow. One nurse could assist during the blocks and one can monitor those who have already been blocked and are waiting transfer to theatre. Two trainees would allow overlap such that the RA consultant could move between patients and the next is already prepared and ready to be blocked – much like a surgical "double list". Rescue blocks could be performed if needed to ensure the patient is completely sorted out prior to going into theatre.

Training benefits

Trainees would be exposed to a consolidated module of RA. They would learn better through repetition over a short period of time. This is in contrast to the current model where the next block might be weeks after the last. Plenty of time to forgot those crucial principles. The reduced time pressure would allow for greater focus on teaching. Interesting cases/anatomy can be shared with the others in the block room rather than a single trainee if this occurred in theatre.

Patient benefits

More patients would have the benefit of RA, performed in a calm, quiet area by people who are not under such time pressure. This would potentially mean they were less painful, safer and better……?

Department benefits

Theatres could run more efficiently due to reduced theatre idle time. PACU transit times would be reduced due to better analgesia and less reliance on general anaesthesia. Some patients could theoretically bypass PACU completely. "Non-regional" anaesthetists would no longer feel under pressure to teach skills outside their comfort zone as another consultant in the block room could supervise their trainees. The centralisation of resources would allow the option of using better, larger, more advanced ultrasound machines. These can provide better imaging and more research opportunities.

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Teaching hospitals should have a block room - Con

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Definition: The block room is a specific area within a theatre suite for the provision of regional anaesthesia (RA) services. Patients receive a peripheral or neuraxial block and are then handed-over to their theatre anaesthesia team for monitoring and care during the surgery. It is staffed by RA faculty and trainees and concentrates the RA expertise for the benefit of the whole Department.

I am not convinced that this is a direction in which we should be moving RA.

The Block room fails at Business School

Most of us work in theatres that are less than brand new. It is a fact of modern surgical life that patients won't all be sitting quietly on the wards awaiting their turn in theatre. The reality is that most arrive on the day of surgery, frequently only a couple of hours prior to a scheduled operation. Traditional systems have been adapted, and adapted again to create admission units, holding bays, high-turnover recovery areas, and storage facilities for high-tech equipment. Space on the theatre floor is at a premium; a business case just on architectural grounds would need to be extremely robust to get the green light. Someone else would need to give up space.

The block room requires people and stuff. Dedicated staff would need to be rostered to the area, and appropriate equipment for blocks, monitoring and resuscitation would need to be available. These resources would have to be in addition to the already staffed anaesthesia locations. Who's paying for that? Where is the return on investment coming from?

The Block room is unprofessional

As Medical Practitioners we are professional care-givers. We are responsible for our own clinical management decisions and have significant input into the way we go about our work. A block room service effectively takes away much of our autonomy. It relies on a roster system to establish the relationships between the chain of anaesthesia provider; it regulates the type of intervention according to the type of procedure; it clouds the lines of responsibility and it subverts democratic collegiality. The presence of regimented and possibly dictatorial leadership is required to keep the Departmental personalities constrained enough to make it work. It erodes our professionalism and demotes us to the role of technician. Just pause and imagine how you're going to make it work at your place.

The Block room is Un-Australian

It is the responsibility of teaching hospitals to prepare trainees for ANZCA Fellowship. The minimum standards, the guidelines and the modules are all designed to produce a balanced clinician capable of providing safe anaesthesia care in a diverse range of environments. ANZCA Fellows work in Australasian hospitals. Not all those hospitals are teaching hospitals, not all of them have state-of-the-art block equipment nor do they all have after-care services that accommodate complex regional techniques. We have to

adapt and overcome. What works in one place will fail in another- the chef needs more than one ingredient in the pantry.

If we are teaching a block room model of regional anaesthesia provision, then we will be neglecting the realities of our actual practice. There is no practical mechanism under Medicare for sharing the billing for a procedure, nor for organising a colleague to come and do your blocks. Mateship and fairness are the cornerstones of the ANZAC spirit; the block room is just plain foreign.

The Block room is a block

A block room model of regional anaesthesia care provides a centralised location for patients to be prepared for surgery. Careful coordination of timing of block performance relative to theatre vacancy is required. A spinal block put in too early significantly erodes the potential efficacy of the intervention. A block started too late, or one a bit difficult to place, causes delay and backlog. Likewise a perfectly-timed block, ready for theatre as planned is difficult to manage if instruments are unavailable or the surgeons change the plan.

Teaching hospitals have a reputation for cumbersome administrative processes. The introduction of mandatory checklists, strict task demarcations and protocols for consent processes can all make the arrival and availability of patients difficult to predict. The tendency within teaching hospitals for teams to on-delegate routine work also contributes to long communication chains and a propensity for no-one to take ownership. There is little to insulate a block room, no matter how well-organised internally, from the many and varied external elements that will impact on its utility. It may be a pressured and frustrating place to be assigned.

The Block room is really the Prof-room

Here we are advocating an entity whereby all patients are funnelled through a service that controls the analgesic intervention prior to releasing the patient to the operative care team. It's a perfect feasting ground for clinical experimentation, log-book massage, and publication churn. There is little flexibility in choice of technique or adaptation to the individual circumstances of the case. Each patient gets the recipe of the day for the designated surgical item number. A simple computer program could perform all the anaesthetic planning, and take on a similar amount of responsibility for its outcomes.

The Block room is for Blockheads

I have been involved in the provision and development of regional anaesthesia services for some time. My clinical practice is heavily weighted towards anaesthesia for orthopaedic surgery, involving elective and acute cases. I practice at 5 different Metropolitan hospitals, some teaching, some not. As a patient I have been on the receiving end of 3 significant surgical procedures, all facilitated by expert regional anaesthesia. I am convinced that although continuous improvement is the mantra, there is little amiss with the current model of care.

The AURORA Project - an update

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Introduction and Background

The Australian and New Zealand Registry of Regional Anaesthesia (AURORA), previously known as the Australasian Regional Anaesthesia Collaboration (ARAC), is a prospective multicentre clinical registry of peripheral nerve blockade practice. AURORA utilises a web-based interface (www.anaesthesiaregistry.org) to collect information on our contemporary clinical practice.

Peripheral nerve blockade (PNB) is a commonly performed procedure for an increasingly aged and co-morbid surgical population. Randomised controlled trials (RCTs) have demonstrated the efficacy of ultrasound (US)-guided PNB compared to nerve stimulator (NS) techniques [1,2], but little is known about the effectiveness and safety of PNB in daily practice outside the confines of a formal clinical trial. Novel US-guided techniques are described and popularised often well before evidence of effectiveness and safety exist. Individual case reports describing complications of US-guided PNB have raised safety concerns [3,5], yet don't inform clinical decision-making by determining the incidence of complications or providing a window into the spectrum of routine care. Clinical registries are valid tools of evidenced-based medicine and are important for measuring outcomes, benchmarking and improving the quality of clinical care [6-11]. Monitoring the quality and safety of an evolving therapy – ultrasound guided PNB compared to traditional techniques, is important for clinical decision-making, development of practice guidelines and healthcare funding. Registries are important 'powerhouses' for driving clinical research and measuring adverse events and clinical outcomes [12]. They are critical for clinical practice improvement. Indeed, experts have called for a clinical results database for every medical condition [11]. Within the field of anaesthesia, registries are especially needed for commonly performed invasive procedures such as PNB [13].

The Australasian Regional Anaesthesia Collaboration's preliminary results till May 31st 2008 have been published [14]. A total of 6950 patients received 8189 PNB's. Of the 6950 patients, 6069 patients were successfully followed up. In these 6069 patients, there were a total of 7156 blocks forming the denominator for late neurologic complications. Thirty patients (0.5%) had clinical features requiring referral for neurologic assessment. Three of the 30 patients had a block-related nerve injury, giving an incidence of 0.4 per 1000 blocks (95% confidence interval, 0.08-1.1:1000). The incidence of systemic local anaesthetic toxicity was 0.98 per 1000 blocks (95% confidence interval, 0.42-1.9:1000). These results indicate that the incidence of serious complications after peripheral nerve blockade is uncommon and that the origins of neurologic features in the postoperative period are most likely to be unrelated to nerve blockade.

Since 2008, ARAC has evolved into the Australian and New Zealand Registry of Regional Anaesthesia (AURORA), a long-term registry of peripheral nerve blockade. This was facilitated by funding from an Australian and New Zealand College of Anaesthetists Project Grant, 2010 – 2012.

Methods

The Human Research and Ethics Committee of each hospital or region contributing to this project have this project approved as a Quality-Assurance Activity or Low-Risk Research. In AURORA, there is no intervention being investigated because this project is a registry of routine clinical practice. This project is a quality assurance project measuring outcomes from routine practice; therefore patient consent is not required.

In 2011, a new online interface (www.anaesthesiaregistry.org) and database were developed so that AURORA could evolve into a long-term register of PNB. Features of this new interface and database include improved security, data quality control [15], functionality, reporting, governance and appearance. Efficiency of data entry into the new interface is enhanced with context specific drop-down menus to facilitate practitioner entry of initial block data at the point of care. All sensitive data that could potentially re-identify the anaesthetist, the hospital or the patient are encrypted for transfer from the data entry terminal to the server. Since implementation in June 2011, 180 hours of database improvements have occurred. The Anaesthesia Registry is physically located in a highly secure data centre located in Melbourne.

Data collected includes initial patient, surgical and block related information. Data is also collected in the Post Anesthesia Care Unit (PACU), in the early postoperative period and at approximately 7-days postoperatively.

AURORA study sites are hospitals, anaesthesia departments and clinical practices (public or private) performing PNBs. AURORA aims to capture every patient who receives peripheral nerve block (PNB) for anaesthesia and/or analgesia in each collaborating site. That is, the target is to capture all PNB performed by all anaesthetists in each study centre, thus reducing a selection bias. This is achievable with good organization and there are several strategies that can be utilised to ensure complete capture of all PNB. These include monitoring the operating lists daily and physical checks by personnel such as a research assistant, pain nurse, or "in charge anaesthetist" checking that all blocks are entered on a daily basis and correcting any deficiencies in a timely manner.

Distinctive features of AURORA include:

- A web-based central database
- Data collection at the individual patient level
- Systematic contact with all patients
- A defined follow-up and investigative pathway
- Clear definition and verification of all key outcomes
- Robust neurological evaluation

An important goal of the delayed follow-up and questionnaire is to determine the presence of symptoms that indicate potential nerve injury. Nerve injury may occur as a result of the anaesthesia, the surgery or be related to patient factors. To detect potential neurological complications patients are asked a standardised set of questions: Do you have any numbness? Do you have any tingling? Do you have any abnormal sensations? Do you have any pain? Do you have any weakness? These questions are asked in relation to the known distribution of the nerve/plexus block. If the patient responds with “yes” to any of the questions, then further queries were made taking into account the anatomy relevant to the surgery and the peripheral nerve/plexus block. Symptoms that are immediately adjacent to the

wound, consistent with normal tissue healing or the initial trauma are not considered relevant in terms of anaesthesia being a causal factor. For patients with ambiguous symptoms or complaints repeat contact is made with the patient. The severity is recorded using a drop down menu on the delayed follow-up page. Weakness or sensory symptoms that are moderate or severe require further follow-up. Repeat follow-up may be required to assess if symptoms are resolving or worsening. Patients with symptoms/signs that are not resolving or worsening required neurologic assessment and referral. In general any symptoms of concern at one month postoperatively should be referred.

Delayed follow-up can occur as early as the fourth postoperative day, for young patients having minor surgery. For patients that have had major surgery it is recommended to visit them on the ward at this time. For some inpatients, they are still recovering from surgery and will have symptoms/signs that could be due to many factors, however establishing a baseline is useful. In addition an information sheet can be given to the patients so they understand the information that is required. For patients for whom English is not their first language this information sheet and contacting a relative (who speaks English) may assist with the AURORA follow-up. Follow-up methods include ward visit, clinic visit, phone call and occasionally review of medical records or other healthcare documentation.

Results update June 1st 2008 and May 31st 2011

A summary of procedures performed according to technology are documented in Figure 1. The patient population registered with AURORA comprises males (51%) with an average age of 58 ± 19 years, weight 80 ± 20 kg and ASA physical status 19%/40%/36%/5% (I/II/III/IV). PNBs were performed for emergency surgery in 16% of patients and a surgical tourniquet was used in 49% of procedures. Patients were unresponsive during performance of trunk (75%), lower limb (15%) and upper limb (9%) PNBs. Ropivacaine was the most commonly used LA, comprising 78% of PNBs, dose 1.5 (1.0 – 2.1) mg/kg median (IQR). Needle types used were short-bevel/Tuohy/hypodermic/other in 86%/5%/3%/8% of PNBs, respectively. Figures 2 and 3 document the steady increase in utilisation of ultrasound technology (either alone or combined with nerve stimulation) to perform PNB. Figure 3 documents a significant decline in the use of nerve stimulator technology alone to perform PNB. Figure 4 gives an example of how ultrasound has changed clinical practice with an increased utilisation of the supraclavicular approach to the brachial plexus.

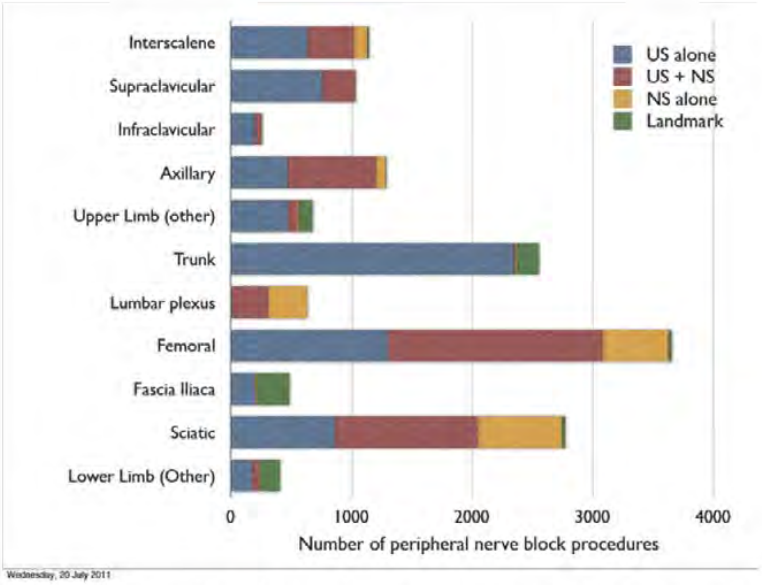

Figure 1. Summary of procedures performed according to technology from June 1st 2008 to May 31st 2011.

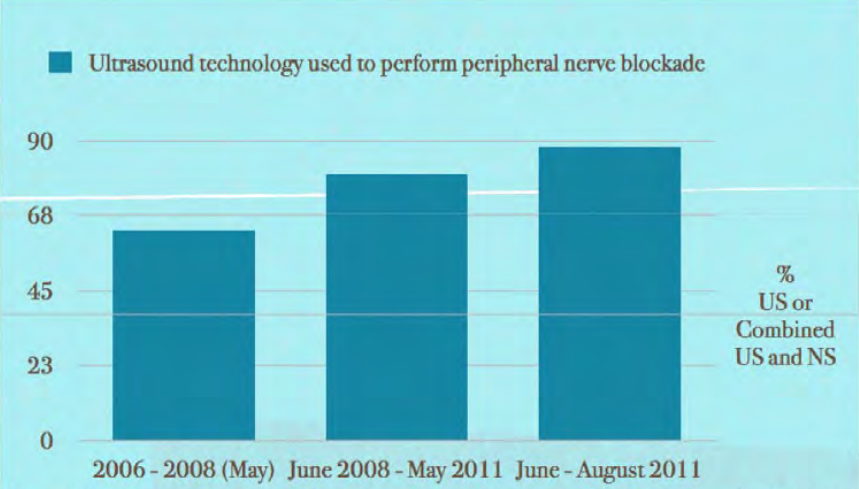

Figure 2. During these time periods there has been increased in utilization of ultrasound technology (either alone or combined with nerve stimulation) to perform PNB

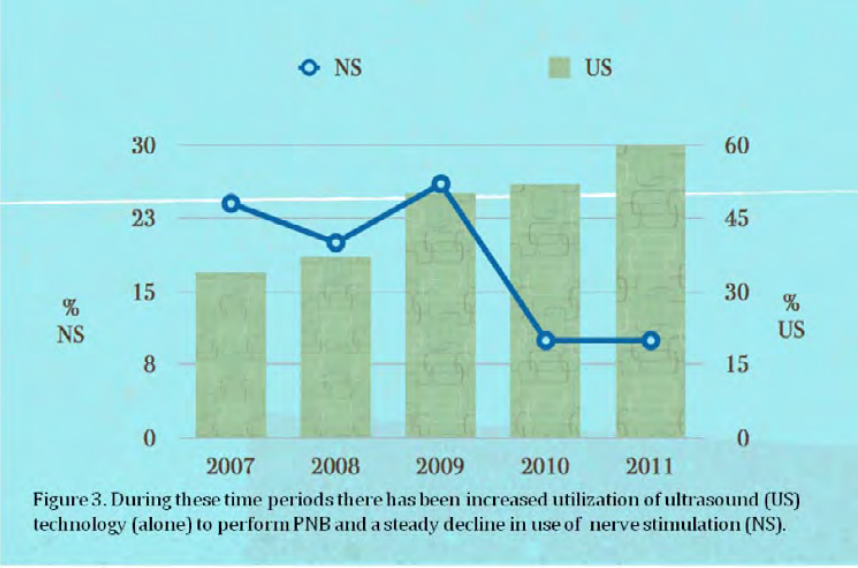

Figure 3. During these time periods there has been increased utilization of ultrasound (US) technology (alone) to perform PNB and a steady decline in use of nerve stimulation (NS).

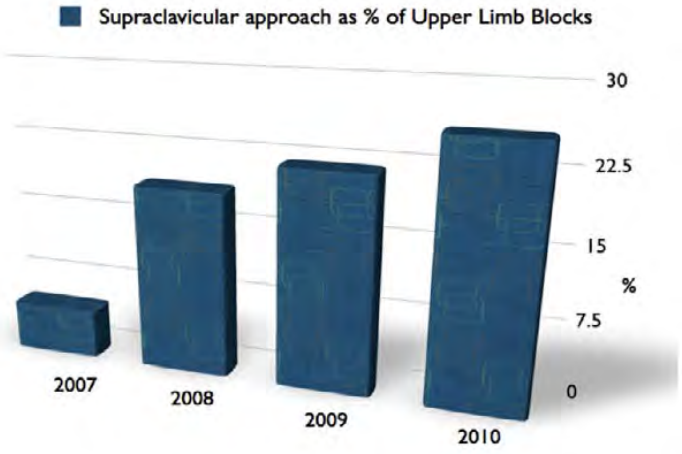

Figure 4. During period 2007 to 2010 there was increased utilisation of supraclavicular blockade compared to other brachial plexus blocks.

Regarding clinical effectiveness, PNB was recorded as successful in 91% and total IV opioid requirements in PACU were 7%, with Figure 5 showing the variation in reported success rate, and PACU analgesic and opioid requirements with PNB type.

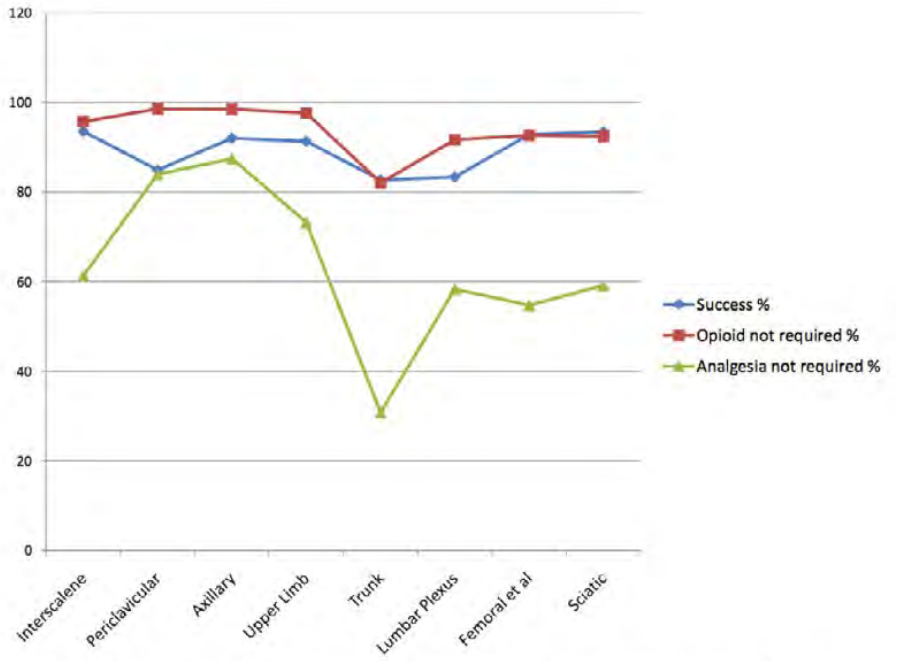

Figure 5. Variation in reported success rate, and PACU analgesic and opioid requirements with PNB type.

Pain score measured in PACU was 0 (0 – 6) and readiness for discharge from PACU was 40 (0 – 100) minutes, both median (IQR). Average PACU pain scores per block type are summarised in Figure 6. Figure 7 documents proportion of patients who would not be happy to have the same PNB if required for a similar operation in the future.

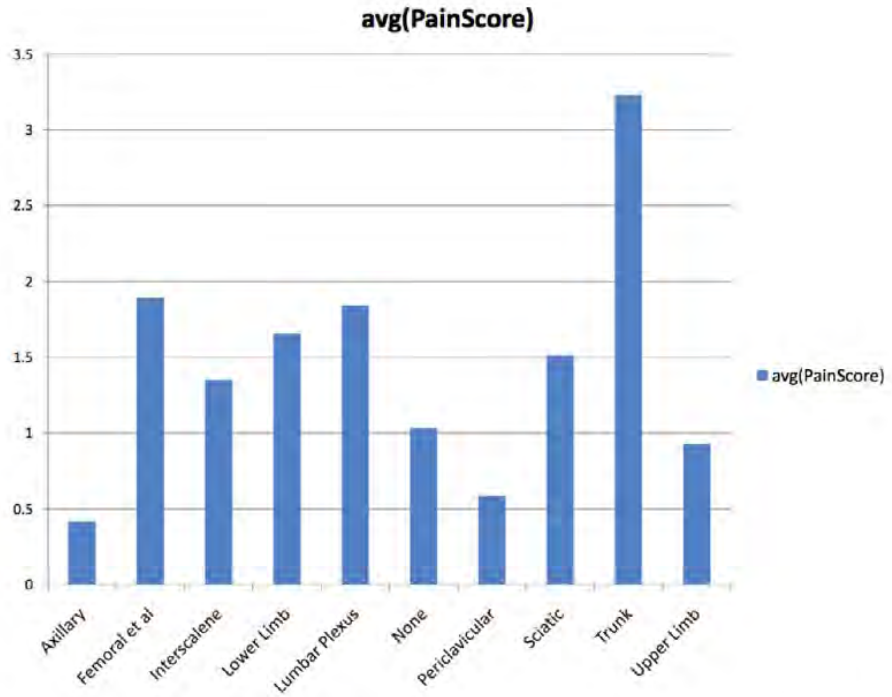

Figure 6. Variation in mean pain scores (numerical rating scale, 0 – 10) in PACU per block type .

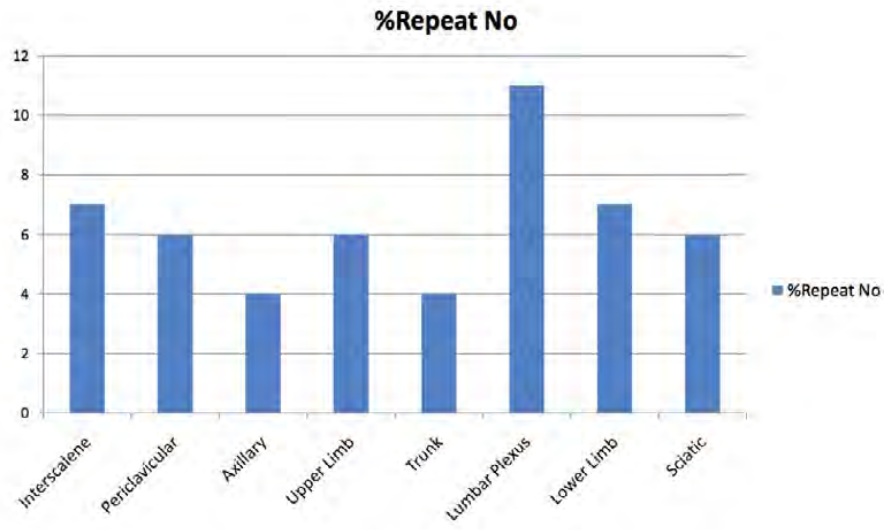

Figure 7. Proportion of patients who would not be happy to have the same PNB if required for a similar operation in the future.

Complications are summarised in Figure 8. Wrong-site anaesthesia was reported in four patients and likely contributory factors were cognitive impairment, language issues, inexperience and inadequate supervision. Wrong-site PNB were all lower limb blocks. Vascular puncture was significantly reduced by the use of ultrasound technology for femoral nerve and axillary brachial plexus blockade. During this reporting period there were: six episodes of mild (CNS excitation) LA systemic toxicity (LAST), two episodes of severe toxicity (seizures) and one patient had a cardiac arrest as a result of LAST. The latter patient, despite having significant co-morbidities, was successfully resuscitated with lipid emulsion therapy as part of advanced cardiac life support. In this current series, there was one pneumothorax following each of SCB and ICB. There were seven patients with nerve injury related to PNB. However, five had co-morbidities that were likely to have influenced the presentation and outcome.

Complication	n	Incidence
Wrong site PNB	4	0.3 (0.07 – 0.7)
Hematoma	30	2.0(1.3 – 2.8)
Vessel puncture	56	3.7 (2.8 – 4.8)
Paraesthesia	210	17.9 (15.5 – 20.4)
Local anesthetic toxicity Minor Major Cardiac arrest Total	 6 2 1 9	 0.4 (0.1 – 0.9) 0.1 (0.02 – 0.5) 0.07 (0.002 – 0.4) 0.6 (0.3 – 1.1)
Pneumothorax	2	0.8 (0.1 – 2.9)
Respiratory depression/arrest	3	0.2 (0.04 – 0.6)
Late neurological deficit Long-term neurological deficit	7 3	0.5 (0.2 – 0.9) 0.2 (0.04 – 0.6)

Figure 8. Complications June 1st 2008 to May 31st 2011. Data are presented as n/1000 (95% CI), Total cohort of 13, 648 procedures used as denominator except for pneumothorax where the denominator used was the combined exposure to interscalene, supraclavicular and infraclavicular blocks (n = 2230).

Discussion

Since 2006, the AURORA project has collected episode and follow up data on over 25, 000 PNBs. This demonstrates the feasibility of such a project. Key findings since 2008 have been an increased prevalence of lower limb PNB consistent with their growing indication for lower limb orthopaedic surgery. There has been increased utilisation of US technology to perform PNBs, with 80% utilising US technology compared to 63% in the previous reporting period 2006 – May 2008. There has also been an increased use of periclavicular block and with it, related complications.

LAST is a rare, but potentially life-threatening complication of a commonly performed anaesthetic procedure, PNB. An estimate of the incidence of LAST and factors contributing to its occurrence are critical for quality improvement. Patient factors, block type, anaesthetic type and dosage may all be relevant and a larger registry may determine likely risk factors and subsequently improve the quality of care [13,16].

Ascertaining the cause of neurologic injury in the postoperative period is challenging with patient, surgical and anesthetic factors influencing the presentation and outcome [14,17-24]. AURORA's study protocol has been established with that in mind, hence the uniform and systematic approach to the follow-up of patients. Overall, the incidence of PNB related nerve or plexus injury is rare, but more documentation is required to clarify the significance of different factors influencing outcome.

Outcomes and significance

The results of AURORA indicate that pneumothorax and LAST are causes of perioperative morbidity due to anaesthesia and that quality improvements should be directed at those outcomes. AURORA is a unique clinical registry capturing key outcomes of a commonly performed anaesthesia procedure (PNB) in Australia and New Zealand and has the potential to improve our knowledge of the effectiveness and risks of PNB. AURORA has the potential to be a unique source of reliable clinical data for evidence-based management, advocacy and the setting of policy. In particular, AURORA is capturing outcomes as PNB is increasingly utilised and evolves due to the increased availability of US technology.

Projects such as AURORA build a culture of safety [25] and there is strong and consistent evidence that public reporting of outcomes stimulates quality improvements in hospitals. AURORA provides a practical method to assess and learn from routine clinical practice and its new, improved web-based interface facilitates its widespread implementation as a quality improvement project.

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Avoiding neurological injury in peripheral nerve blocks

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Nerve injury following peripheral nerve blockade (PNB) is a potentially devastating complication that can result in permanent disability [1]. Data from a recent review of published studies suggests that the incidence of neurologic symptoms following PNB varies depending on the anatomical location, ranging from 0.03% for supraclavicular blocks to 0.3% for femoral blocks to up to 3% for interscalene blocks [2]. Fortunately, the vast majority of these neuropathies appear to be temporary rather than permanent, and resolve over weeks to months.

The exact aetiology of neurologic injury related to PNB remains unclear in many instances. Suggested aetiologies include mechanical trauma from the needle, nerve edema and/or haematoma, pressure effects of the local anaesthetic injectate, and neurotoxicity of the injected solutions (both local anaesthetics and adjuvants, among others (i.e. adrenaline) [3]. Confounding factors that may play a role in nerve injury include pre-existing neuropathies (e.g. diabetes mellitus), surgical manipulation, prolonged tourniquet pressure or compression from postoperative casting [4].

It is well established that direct injection into peripheral nerves (e.g. accidentally during IM administration) can result in nerve injury [5]. As a result, regional anaesthetists have traditionally adopted the stance that an intraneural injection of local anaesthetic solutions results in nerve injury following PNB. This stance, however, has recently been challenged by several somewhat controversial studies that suggest that the relationship between intraneural injection and nerve injury is more complicated than initially thought. This shift in paradigm has influenced both the controversy and implications and the methods of peripheral nerve blockade. The goal of this review is to summarise the current knowledge on the relationship of intraneural injection and peripheral nerve injury.

Histology and Histopathology of Peripheral Nerves

Knowledge of the functional histology of nerves is essential to understanding of the consequences of intraneural injection. Nerves are made up of fascicles that are supported and enveloped by *perineurium* and a loose collection of collagen fibres termed the *epineurium* (Figure 1). The epineurium is easy permeable and carries the nutritive vessels of larger nerves. Each fascicle is made up of bundles of nerve fibres (axons) and their associated Schwann cells held together by a tough squamous epithelial sheath called the *perineurium*, which acts as a semi-permeable barrier to local anaesthetics. The nerve fibres are supported within the perineurium by a delicate connective tissue matrix called the *endoneurium*, which contains capillaries that arise from the larger epineurial vessels.

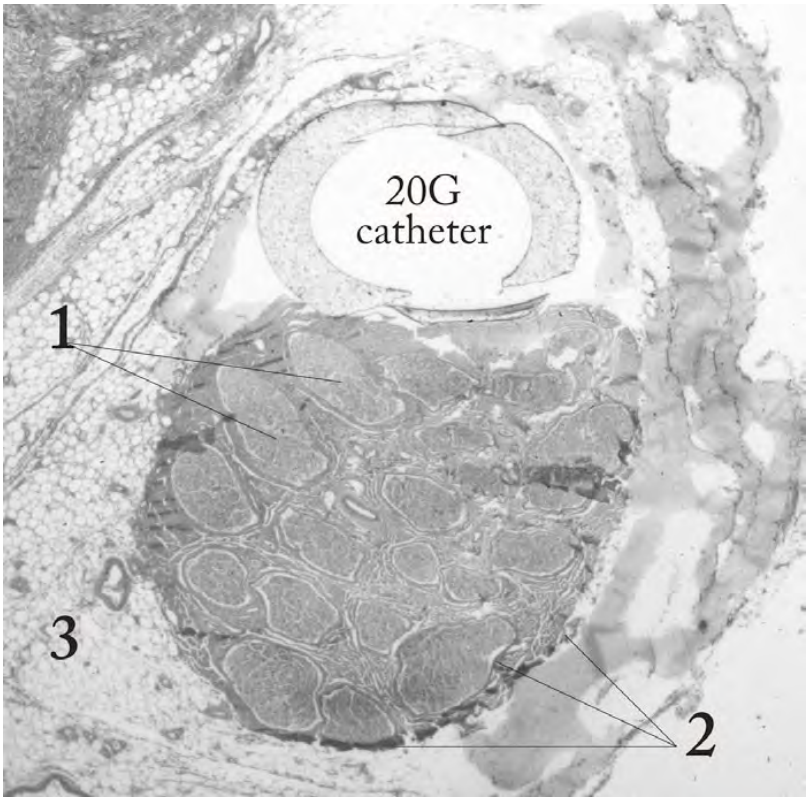

Figure 1. Histology of the peripheral nerve. Bundles of nerve fibers (1) can be seen within a fascicle, which is surrounded by perineurium (2). The loose, connective tissue of the epineurium (3) surrounds the fascicle. A 20-gauge plastic catheter has been inserted for comparison into the epineurium immediately adjacent to the fascicle.

Peripheral nerve lesions can be classified in terms of their degree of functional disruption [6]. *Neuropraxia* refers to a mild insult in which the axons and connective tissue structures supporting them remain intact. This type of injury is often associated with focal demyelination, and is generally reversible over the course of weeks to several months. Axonal interruption with conservation of the neural connective tissues is termed *axonotmesis*. Regeneration at a rate of 1-2 mm/day occurs, and recovery is generally favourable, although not always complete. *Neurotmesis* represents complete fascicular interruption, including the axons and the connective tissue supporting tissues. Because the nerve is severed, recovery is dependent on surgical re-approximation of the two stumps. Even with prompt surgical intervention, recovery is often poor. It is important to note that most nerve injuries are mixed, with different fascicles exhibiting characteristics of these three different injury types.

The Problem…or Is It?

Selander et al. provided evidence of the deleterious effects of intraneural injection over 30 years ago [7]. Since then, the objective of peripheral nerve blockade has been to deposit local anaesthetic in the vicinity, but not within, the substance of the nerve. This tacit convention has been challenged in recent years with the publication of a series of reports suggesting that intraneural needle placement, and indeed injection of local anaesthetic, may not necessarily result in detectable clinical injury. In 2004 Sala-Blanch et al. described two cases of placement of a catheter within the epineurium of the sciatic nerve, confirmed by computerised tomographic imaging [8]. Both patients demonstrated clinically efficacious blocks, without postoperative neurologic deficit. The advent of ultrasound-guidance for nerve blocks has likely led to an increase in the recognition of inadvertent intraneural injections. Accidental femoral [9]

and musculocutaneous [10] intraneural injections have been described, as evidenced by nerve swelling on the ultrasound image, both without lasting neurologic effect.

In 2006, Bigeleisen published a series of axillary brachial plexus blocks performed on 22 patients undergoing thumb surgery [11]. Using ultrasound guidance, he deliberately attempted to place the needle intraneurally and inject 2-3 ml of local anaesthetic, which resulted in 72 intraneural injections as evidenced by nerve swelling. Despite the common occurrence of paraesthesia or dysaesthesia (66 times), none of the patients were found to have any neurologic deficit up to six months postoperatively.

Similarly, Robards et al. studied 24 patients receiving sciatic nerve blocks in the popliteal fossa using both nerve stimulation and ultrasound guidance [12]. The end-point for needle advancement was a motor response using a current intensity of 0.2-0.5 mA, or an apparent intraneural needle tip location, whichever came first. These investigators found that the motor response could only be obtained upon entry of the needle into the nerve in 83.3% of patients; in the remaining 16.7%, a motor response with a stimulating current of 1.5 mA could not be obtained, even when the needle tip was intraneural. There was no postoperative neurologic dysfunction.

Taken together, these studies suggest that violating the epineurium *and* injecting within the substance of the nerve is not necessarily as harmful as the early animal experiments may have led us to believe. In addition, many regional anaesthetists have concluded, especially in light of the results of Robards et al., that many blocks performed in the past, without the benefit of ultrasound visualisation, have probably in fact represented intraneural injections. This is undoubtedly a beneficial circumstance for our patients, who do not suffer nerve injury to the degree that we may previously have expected. The question, then, is why not?

Extrafascicular and Intrafascicular Injections

A needle placed within a compound nerve can be in one of two locations: within the loose epineurial matrix that surrounds the fascicles, or inside a fascicle itself. It is well established that injection of even very small amounts of local anaesthetic within the fascicle can lead to widespread axonal degeneration and permanent neural damage in animals, while extrafascicular injection results in normal nerve architecture [7,13]. Part of this can be explained mechanically, as the perineurium, a tough multilayer epithelial sheath, is not prone to ready expansion. Intrafascicular pressure rises on injection, and can remain higher than the capillary perfusion pressure longer than the duration of the injection itself, predisposing to neural ischaemia and inflammation [14]. Furthermore, pressure curves derived from intrafascicular versus extrafascicular injections in canine sciatic nerves show that a pattern of very high initial injection pressures followed by a sharp drop to baseline is associated with poor outcome and severe neural histologic damage, and may suggest fascicular rupture [15]. On the other hand, injections into the compliant epineurial space appear to be associated with a minimal rise in pressure, which can be explained by its loose and accommodating stromal architecture.

The risk of an intrafascicular injection differs from site to site in the peripheral nervous system, and correlates with the cross-sectional fascicle-epineurium ratio. For example, the sciatic nerve at the popliteal fossa contains more non-neural tissue than fascicles in its cross-sectional area, which corresponds with its low incidence of post-PNB neuropathy [16]. By contrast, the brachial plexus at the level of the trunks contains much more neural than connective tissue—a needle entering the nerve here is more likely to encounter a fascicle on its trajectory which may contribute to the disproportionately higher rate of postoperative

neuropathy following PNB with interscalene blocks [17]. As peripheral nerves move away from the neuraxis, the ratio of connective tissue to neural tissue within the nerve tends to increase. This helps to explain why Bigeleisen had no neurologic deficits after the 72 intraneural injections at the axilla: the brachial plexus elements below the clavicle have a ratio of connective tissue to neural tissue of approximately 2:1, whereas the more proximal trunks and divisions have a ratio of 1:1 [18].

Mechanisms of Nerve Injury Following Intraneural Injection

Once the perineurium is breached, the spectrum of subsequent injury is wide, and is multifactorial.

Needle trauma

The mechanical disruption of the perineurial sheath may result in the leakage/herniation of endoneural contents [19]. However, the composition of the injectate may play a larger role in the outcome of intrafascicular injection. For example, normal saline injected into fascicles did not cause any damage in one study, suggesting that mere puncture of the perineurium does not necessarily result in clinically overt injury [13]. On the other hand, nerve puncture with intravenous cannulae or electroneurography needles have been shown to result in lasting neurologic deficit [20-22]. A variety of cellular changes accompany needle trauma, including alterations in membrane channel expression, activation of signal transduction, neuropeptide production, and an overall increase in excitability at the dorsal horn [23,24]. When pencil point needles are used to puncture peripheral nerves, smaller needles (24 G) lead to less nerve injury than larger needles (19 G) [25].

Despite the concern over fascicular puncture, the fascicle may be difficult to penetrate under normal PNB conditions. Early work by Selander et al. in rabbits demonstrated that needle tip characteristics influenced the likelihood of fascicular penetration [26]. This study demonstrated that long-bevel (12-15º) needles were more likely to puncture the fascicle than short-bevel (45º) needles, and resulted in the author advocating for their use during PNB. A more recent study compared blunt (30º) versus sharp (15º) needles by passing these needles through a cadaveric sciatic nerve and examining the nerve microscopically afterward for signs of fascicular damage [27]. While a total of 134 fascicles were identified as being in contact with the needle tracks, only 4 fascicles were damaged, all of which belonged to the sharp-tip group. These data suggest that a needle passing through a fascicle is likely to only encounter epineurium, and may in fact displace the tough fascicles away from the needle path. While blunt needles are less likely to enter the fascicle, evidence suggests that once penetrated, blunt needles appear to cause a greater degree of injury compared to sharp needles, especially if the sharp needles are oriented with the bevel in the same direction as the nerve fibres (i.e. not cutting transversely across the fibres) [28].

Toxicity of local anaesthetics and additives

While it is clear that all local anaesthetics are potentially neurotoxic [29], the mechanism remains unclear. Proposed mechanisms include increases in intracellular calcium concentration, disturbed mitochondrial function, interference with membrane phospholipids, and cell apoptosis [30-33]. The perineurium and blood vessel endothelium serve as a barrier to entry into the fascicle. However, local anaesthetics placed within the epineurium have been shown to cause altered perineural permeability and fascicular edema, leading to compression of the fascicle and reduced neural blood flow [13,34]. This effect appears to be dose-dependent.

Intraneural administration of local anaesthetics exposes the axons to higher concentrations of drug than extraneural application. One study comparing the extraneural, extrafascicular and intrafascicular administration of ropivacaine 0.75% showed that histologic damage was least severe extraneurally and most severe intrafascicularly [35]. However, even when injected inside the epineurium, ropivacaine 0.75% has been shown by others to have no adverse effect on functional recovery [36]. Ester local anaesthetics such as tetracaine and chlorprocaine were shown in some studies to cause a greater degree of injury than those of the amide group, but those conclusions have been challenged by more recent data [34,37]. What is well-known is that the injection of local anaesthetics into the fascicle results in widespread and immediate axonal injury [14].

Local anaesthetics alone are capable of decreasing neural blood flow. Lignocaine 2% reduces neural blood flow in rat sciatic nerves by 20-40%, and this difference persists after wash-out of the local anaesthetic solution [38,39]. Increasing concentrations of lignocaine appear to reduce neural blood flow further, while the reverse is true for bupivacaine. Altering the concentration of tetracaine appears to have no effect on neural blood flow. Various concentrations of levobupivacaine and ropivacaine have been found to significantly reduce rat sciatic nerve blood flow [40].

Adrenaline is a common adjuvant that is used to prolong the duration of blockade and to warn of intravascular injection/absorption. At concentrations of 5 mcg/ml and 10 mcg/ml adrenaline reduces neural blood flow by 20% and 35%, respectively [39]. In contrast, at lower concentrations (2.5 mcg/ml) neural blood flow increases by 20% transiently before returning to baseline, suggesting that at lower concentrations the beta-adrenergic effects predominate. The effects of combining lignocaine and adrenaline are additive—a solution of 2% lignocaine plus 5 mcg/ml of adrenaline reduced neural blood flow by 80% [38].

The clinical significance of this reduction is unknown. Clearly, thousands of blocks are performed using a combination of local anaesthetic and adrenaline with no neurologic compromise. This reinforces the fact that nerve injury is multifactorial and one theoretical aspect may be insufficient to consistently cause injury.

Prevention of Peripheral Nerve Injury

Several techniques have been advocated as assisting in safe practice during the performance of PNBs. The merits of each in preventing nerve injury will be addressed individually.

Pain on injection

Pain on injection has traditionally been taught as a reliable and effective means to guard against intraneural injection because intraneural injections are thought to be exquisitely painful. However, there are multiple problems with this logic. First, pain is notoriously difficult to evaluate in terms of intensity and quality. Consequently, differentiating between a benign, commonly present discomfort during injection of local anaesthetic (pressure paraesthesia) and that of intrafascicular injection can be elusive. Second, various patient conditions (e.g. diabetes mellitus, peripheral neuropathy) may interfere with pain perception. Third, there appears to be little evidence that pain on injection is either sensitive or specific. Fanelli et al. conducted a prospective study of nearly 4000 patients receiving multiple-injection PNBs and found that the overall rate of neurologic complications was 1.7%, independent of whether the patient reported a paraesthesia or not [41]. In other words, it does not appear to matter whether the patient reports a paraesthesia or not—they have an equal likelihood of postoperative neuropathy. Bigeleisen's report of 72 intraneural injections was associated with 66 reports of paraesthesia or dysaesthesia, yet none of the patients had neurologic

complications, suggesting that the symptom itself has a very low specificity for complications [11]. Fourth, the nature of nerve injury might preclude its use as a useful monitor: by the time a patient registers pain, communicates it to the anaesthetist, and the injection is halted, the damage is likely to have been done. Since a fraction of a milliliter is all that is required to cause irreversible fascicular damage, the patient's subjective symptom may be too late [7,15]. Finally, there are situations in which performing PNBs in an asleep/heavily sedated/blocked patient might be the safest approach, e.g. paediatric cases, mentally incompetent patients, the traumatically injured, patients needing rescue or repeat blocks, etc. The use of more objective monitors, as listed below, may provide increased confidence that an intrafascicular injection can be avoided, when compared to a subjective patient symptom.

Electrical nerve stimulation

Electrical stimulation is a means to locate nerves, but also may be used to ensure that the needle is outside the epineurium. Voelckel et al. demonstrated that percutaneous sciatic blocks in pigs performed with a motor response at < 0.2 mA resulted in inflammatory nerve changes in 50% of the specimens, compared to none when the motor response was achieved at 0.3-0.5 mA [42]. Others have investigated the relationship between current intensity and needle-nerve distance in pigs and found that, while the relationship is unpredictable outside the epineurium, a motor response at a current intensity of 0.2 mA or less is always associated with intraneural needle placement [43,44]. These findings have been confirmed in a clinical study of patients undergoing ultrasound guided supraclavicular block, in which minimal threshold currents were recorded at extraneural and intraneural positions [45]. The investigators found that no motor response could be elicited at a current of 0.2 mA or less unless the needle tip was intraneural.

These studies suggest that, while neurostimulation techniques may not be a highly sensitive method of detecting intraneural needle tip position (i.e. high current intensities may still be required to elicit motor responses), neurostimulation appears to have a high specificity for identifying intraneural needle tip placement (i.e. motor response at ≤ 0.2 mA obtained only with intraneural needle tip location), using NO motor response at ≤ 0.2 mA as a cut-off for safe practice.

Ultrasonography

Ultrasound guidance is theoretically an attractive means of preventing intraneural injection due to real-time imaging of the needle and nerve. Indeed, nerve swelling visualised on the sonographic image appears to represent true histologic intraneural injection as evaluated by the presence of India ink staining within the epineurium [44,46]. However, the clinical implications of this are also unclear, as nerve swelling and even histologic changes associated with nerve injury appear to not result in detectable neurologic deficit in pigs, although there may be subtle changes that cannot be assessed by the evaluators [47].

Ultrasound guidance may not be a substantially effective means of preventing nerve injury. The reliability of ultrasound to keep the needle tip extraneural is entirely dependent on the skill of the operator and the imaging characteristics of the needle and tissue. Several case reports of accidental nerve (and vascular) puncture despite the use of ultrasound guidance highlight this [9,10,48]. Furthermore, at the present time the resolution of the sonographic image is such that it would be impossible to tell if the needle tip was intrafascicular or extrafascicular, which is the critical anatomic differentiation to make to avoid nerve injury. Finally, as is the case with paraesthesia, by the time the nerve is seen swelling on the image, the damage may have already been done if the needle tip is inside the fascicle.

Injection pressure monitoring

The crux of the intraneural injection problem thus far appears to lie in the avoidance of penetrating the perineurium and entering the fascicle. Hadzic and colleagues demonstrated in a canine model that the presence of a high opening injection pressure (> 20 PSI) is a very sensitive (if not highly specific) sign of intrafascicular needle tip placement, whereas extrafascicular needle tip placement is associated with low (<10 PSI) pressures [15]. Another dog study showed that some, but not all, intraneural injections resulted in high (> 20 PSI) pressures, whereas high pressures were absent during extraneural injection [49]. More importantly, every dog associated with high pressure injection demonstrated neurologic deficits and severe axonal damage after the block, in contrast to normal neurologic and histologic findings following any low pressure injection (extra or intraneural). Indeed, PNBs associated with high injection pressure, despite a lack of paraesthesia, have been reported to result in permanent neurologic injury [50].

Given this, safe practice should include the assessment of the resistance to injection with every PNB. An assessment of injection resistance is often assessed using a “syringe-hand-feel” technique. However, it has been demonstrated (in at least two models) that anaesthetists were unable to gauge injection pressure by using a syringe-hand-feel subjective technique [51,52]. Therefore, if monitoring of resistance to injection is to have clinical merit, objective monitoring of injection pressure should be utilised to standardise the injection force. This may be achieved by use of commercially available in-line devices, or with the use of a “compressed air injection technique”[53]. One shortcoming of injection pressure monitoring is that injection pressure is highly sensitive but lacks specificity. In other words, absence of high injection pressure appears to effectively rule out an intra-fascicular injection. However, high injection pressure can be caused by PNB needle obstruction, attempted injection into a tendon, or tissue compression caused by the ultrasound transducer.

Future Directions

The regional anaesthesia community is witnessing the beginning of a paradigm shift in the thinking surrounding intraneural injection during PNB. Clearly they can be performed safely in certain patients or in certain anatomical locations—the question is: should they? Intraneural extrafascicular injection of local anaesthetic often results in histologic axonal damage, despite no overt patient symptoms. That picture may change in patients who have pre-existing or subclinical neuropathy. It is important to note that the studies demonstrating safe intraneural injections in humans deliberately excluded patients with pre-existing neuropathy.

There are very few of us who suggest that deliberately placing local anaesthetic within the nerve at the interscalene level is safe practice. However, distal nerves may in fact be much more forgiving, owing to their increased ratio of non-neural tissue to neural tissue. In particular, the sciatic nerve at the popliteal fossa appears to be quite resistant to injury following intraneural injection, or even intraneural catheter placement [54,55]. In fact, it has been noted that intraneural injection of local anaesthetic in the popliteal sciatic nerve leads to a rapid onset of sensory and motor blockade, without complications [55]. Some practitioners now routinely attempt to place the needle tip within the epineurium at this location, in an attempt to hasten onset, improve block success, and decrease the total amount of local anaesthetic required. Only with objective injection pressure monitoring can this practice be advocated, as the need to remain extrafascicular is paramount.

One of the challenges facing us will be to elucidate the precise factors that provide for a safe intraneural injection, whether anatomical (popliteal sciatic versus subgluteal), technological

(injection pressure monitoring, improved resolution of ultrasound imaging), educational (improved training) or otherwise. More clinical research is needed to clarify the safety of intraneural injection in various nerves such as the femoral nerve, and distal nerves of the upper and lower limbs. This should be undertaken with care, and with proper safeguards to prevent penetration of the perineurium. Lastly, intraneural injection may allow us to substantially reduce the volume and/or concentration of local anaesthetic required for effective nerve block [54]. This is a worthwhile avenue to explore, both in terms of the implications for nerve injury and for reducing the potential for systemic local anaesthetic toxicity.

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Management of the patient with a neurological deficit

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Background

Postoperative neurological deficits are a well-known and potentially debilitating clinical problem. Prevention of nerve injury is part of the process of perioperative care - *primum non nocere*. Serious neurological complications attributable to regional anaesthesia are infrequent or rare, but are a common cause of medical litigation invoking the legal doctrine – *res ipsa loquitur* (the thing speaks for itself). This presumption can be rebutted by showing that the event was an inevitable accident and had nothing to do with the clinician's responsibility of control or supervision. Fortunately, most neurological deficits associated with surgery and regional anaesthesia resolve with time and have a good outcome [1-4]. Despite this, the patient presenting with a postoperative neurological deficit is a cause for concern for both clinicians and patients. A postoperative neurological deficit may impair recovery from surgery, delay discharge and provoke anxiety and stress regarding aetiology and prognosis. The pathogenesis of peripheral perioperative nerve injury is complex with multiple potential etiologies and mechanisms (Table 1). Mechanisms of injury in the perioperative period include stretch, compression, ischaemia, metabolic, direct trauma and laceration [5,6]. If a patient presents with a postoperative neurological deficit, considering causes other than regional anaesthesia is appropriate. Patient, surgical and anaesthetic factors contribute and a broad approach to investigation is important [6].

Table 1. Potential mechanisms/aetiologies of perioperative nerve injury

Anaesthetic	Direct trauma with needle or catheter Direct nerve perforation, injury to fascicle and/or perineurium Pressure effect of local anesthetic injectate Nerve oedema and/or haematoma Direct toxicity of local anaesthetics and adjuvants Concentration and time dependant (in-vitro studies) Decreased neural blood flow Needle size and type Positioning
Patient	Diabetic mellitus, Ulnar neuropathy, Carpal tunnel syndrome, Peripheral neuropathies, Chemotherapy, Vascular disease, Multiple sclerosis, Age, Proximal nerve root compression, Spinal canal stenosis
Surgical	Tourniquet pressure and duration Compression, Contusion, Stretch, Transection Compressive dressings and casts Improper positioning
Other	Inflammatory- immune

Patients with subclinical pre-existing neurologic conditions may develop overt neuropathies in the postoperative period. When the application of one or more insults on a dysfunctional but clinically normal nerve results in new neurologic symptoms, it is termed the "double crush"

syndrome [7]. Examples of this include severe brachial plexopathy after interscalene blockade in a patient previously exposed to cis-platin [8], and in a patient with multiple sclerosis [9]. Patients with diabetes mellitus, vascular disease, a history of cigarette smoking may be at higher risk [10]. Theoretically, patients with preoperative ulnar neuropathy, carpal tunnel syndrome or proximal nerve root compression are at increased risk of developing postoperative neurology. Spinal canal stenosis has also been documented as a risk factor [11].

In one large retrospective study, surgical specialties associated with perioperative peripheral nerve injuries were neurosurgery, cardiac surgery, general and orthopaedic surgery [12]. Orthopaedic surgery often requires specific positioning, the application of significant forces (e.g. during prosthesis insertion) and a pneumatic tourniquet all of which increase the risk of postoperative nerve injury. Peroneal palsy is a well-known complication of total knee arthropasty [13-18]. Differentiating a sciatic nerve injury due to sciatic nerve blockade from a peroneal palsy due to surgery is challenging and patients with a preoperative valgus deformity may be at increased risk of peroneal palsy. Tourniquet application causes nerve damage from either ischaemia or mechanical deformation [5,19,20]. The large diameter neurons are mostly affected with the most significant injury occurring at the edge of the tourniquet resulting in failure of transmission of fast conducting myelinated fibres with irreversible damage occurring in 2 – 4 hours. Tourniquet neuropathy results in loss of motor function, diminished touch, vibration and position sense, but preserved senses of heat, cold and pain [20]. Attempts to minimise nerve damage include reducing the inflation pressure to just above arterial, decreasing the duration of inflation and using a wider cuff.

In the above-mentioned study [12] epidural and general anaesthesia were noted to be associated with perioperative peripheral nerve injuries. The hazard ratios (95% CIs) were 4.1 (2.7 - 6.3) and 2.8 (1.7 – 4.6) respectively, however this is in the context of an overall incidence of nerve injury of 0.03%. Peripheral regional anaesthesia risk was assessed during a 20-year cohort study conducted at the Mayo Clinic in Rochester [21]. The study included more than 12, 000 total knee arthroplasty patients. Peripheral nerve blockade (PNB) was not associated with peripheral nerve injury. However, some caution is required because patients with peripheral nerve injury were less likely to fully recover if they had received PNB. Increased age and tourniquet time were associated with increased risk of nerve injury.

Post-surgical inflammatory neuropathy is a documented cause of perioperative neuropathy. Inflammatory neuropathies can present as pain and weakness in a focal, multifocal or diffuse pattern, and include a spatio-temporal separation from the site and time of surgery. Staff et. al. published a series of 33 patients, of whom 23 had nerve biopsies as part of their investigations [22]. Nerve biopsies were abnormal in 21 of 23 cases and histological findings included epineural perivascular lymphocytic inflammation, axonal degeneration and microvasculitis. This series indicates that an inflammatory-immune mechanism may be an important non-mechanical etiology of postoperative neuropathy. The incidence and significance of this entity is unknown.

In the Australasian Regional Anaesthesia Collaboration (ARAC), more than 7000 PNB were audited for neurological complications. Thirty patients (0.5%) had clinical features requiring referral for neurologic assessment. Three of the 30 patients had a block-related nerve injury, indicating that the origin of most abnormal neurologic symptoms/signs in the postoperative period is likely to be unrelated to nerve blockade [23].

Management of a Neurological Deficit

Management begins with a thorough clinical assessment, comprising history and examination with the goal of identifying all risk factors. These include anticoagulation for suspected central deficits or peripheral deficits following a deep peripheral block. Identifying symptoms suggestive of a preoperative neuropathy is important. Initial assessment is directed towards determining if the process is affecting a single peripheral nerve, multiple peripheral nerves, a plexus, a nerve root(s) or the central neuraxis. Ongoing review, documentation and effective communication with the patient and other health professionals are essential.

A. Central neuraxial deficits: Epidural haematoma and abscess are well known but fortunately rare risks of neuraxial blockade [24]. Presenting features of spinal cord compression include back pain, decreased sensation below the level of compression, paralysis of limbs below the level of cord compression and incontinence and/or urinary retention. Following the diagnosis (obtained from MRI), a prompt treatment plan including urgent referral to a neurosurgeon, should be activated in order to avoid a poor outcome. An immediate laminectomy is necessary (except in the cases in which a spontaneous resolution can be expected) as neurological outcome is mainly related to the preoperative neurological impairment, the duration of spinal cord compression and the time interval between the onset of symptoms and maximal deficit [6].

B. Peripheral deficits: Patients with an acute peripheral motor deficit of duration longer than that expected from known pharmacological and anatomical factors should be referred to for neurological review. Consider imaging to rule out a compressive haematoma. Patients with no motor deficit can be observed with reassurance. Sensory symptoms, while appearing relatively benign are often disturbing for the patient. Sensory symptoms include simple non-painful paraesthesia, dysaesthesia, allodynia and hyperalgesia. Persistent non-painful paraesthesia is the most common presentation. The neuropathic features are especially disturbing and should be treated with anti-neuropathic drugs. Referral to a pain specialist is also advised. The distribution of these symptoms is important and those matching the known distribution of the nerve block, that are not resolving should be referred to a neurologist. In ARAC the incidence of the presenting features of patients referred to neurologists were paraesthesia n=16 (53%), motor deficit n=4 (13%), neuropathic n=9 (30%) and incidental n=1 (3%).

Trigger for referral to neurologist

The Australian and New Zealand Registry of Regional Anaesthesia (AURORA), formerly ARAC, has a clinical pathway summarised in Figure 1. Triggers for non-acute referral to a neurologist are: a new onset of motor and/or sensory deficit; non-resolving paraesthesia; pain; allodynia; or dysaesthesia and any concern expressed by the surgical team regarding the potential for an anaesthetic-related neurological deficit. Patients with symptoms that are clearly resolving or neurological features that are clearly the result of the surgery are not referred. Assessment by a neurologist would usually comprise history, examination, documentation and investigation when appropriate. Investigations would ideally include electrophysiology [nerve conduction studies (NCS) and/or an electromyogram (EMG)]. For patients with sensory symptoms persisting at one month postoperatively in the distribution of the nerve block, refer to a Neurologist. The primary objectives of the referral are to determine if the symptoms, signs and investigations are consistent with a neuropathy. Localising the lesion if present (e.g. nerve root, peripheral nerve, muscle, neuromuscular junction), determining severity and likely prognosis are important. The specific question that needs to be

answered is: Is there any evidence on NCS/EMG of a deficit of peripheral nerve function and at what level? Localising the level of the deficit is critical in deciding if there is an anaesthesia related injury. With this in mind it is important for the referring doctor to give specific information about the location of the nerve block. Examples are: this brachial plexus block was performed at the level of the cords or the sciatic nerve block was performed at the infragluteal level.

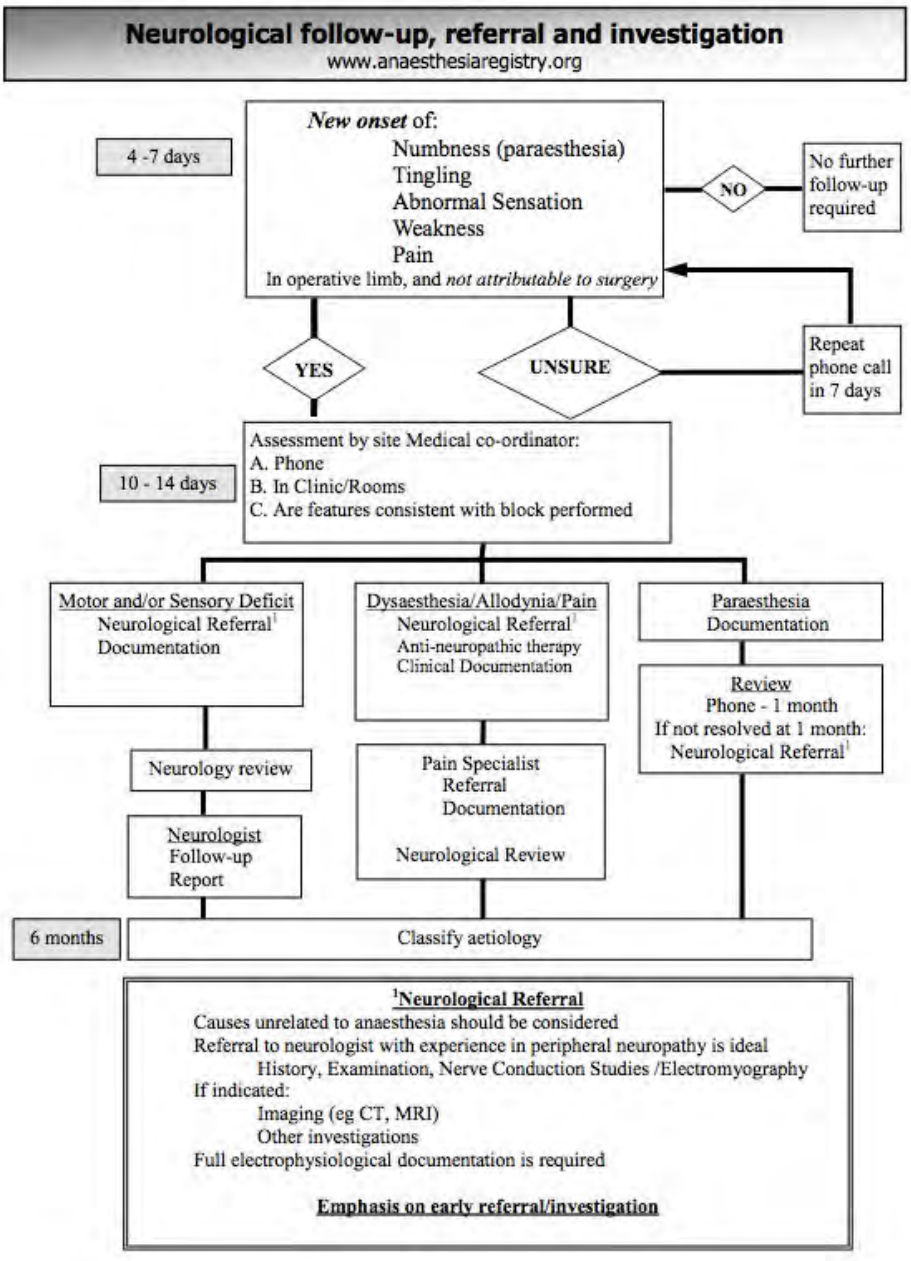

Figure 1. The clinical pathway used by The Australian and New Zealand Registry of Regional Anaesthesia (AURORA), for non-acute Neurological follow-up, referral and investigation.

Comments on electrophysiology

Information on electrophysiology can be obtained in the following articles [1,25-27]. The objectives of the electrophysiology studies are to diagnose or exclude a peripheral nerve lesion or neuropathy following clinical assessment. NCS and EMG are considered an extension of the physical examination. NCS and EMG do not replace careful history and

examination of the patient. NCS and EMG have an important diagnostic role in acute, asymmetric, multifocal or severe disabling neuropathies. NCS/EMG may locate the site of the deficit but not always determine the cause. Additional investigations may be required to determine cause. Electrophysiological tests would normally include motor NCS, sensory NCS and EMG, but will depend on the clinical assessment. Comparison with a non-surgical limb may be important to diagnose a pre-existing neuropathy. The timing is important and it is often advised to delay NCS/EMG till 3-5 weeks postoperatively, because it may take that period of time before pathological changes become apparent [1]. Alternatively, electrophysiological abnormalities in the early postoperative period may indicate a pre-existing neuropathy, and clearly that information is of importance. Sequential studies may be required for the diagnosis to be made with confidence.

During the test answers to the following questions should be answered:

1. Are the conduction velocities normal?

2. Are the Compound Muscle Action Potentials (CMAPs) normal is size and shape?

3. Does the CMAP alter in size, shape or duration between stimulation points?

4. Can the nerve lesion be localised by presence of a conduction block or focal slowing?

Motor Nerve Conduction studies: are performed by electrical stimulation of a nerve and recording the compound muscle action potential (CMAP) from surface electrodes overlying the muscle innervated by that nerve. CMAP is a summated voltage response from the individual muscle fibre action potentials. Measured parameters include latency, duration and amplitude. If the nerve is stimulated at different locations (e.g. the median nerve at the wrist and elbow), the CMAP will be of similar shape and amplitude but the latency will be greater for the elbow stimulation because of the longer distance between the stimulating and recording electrodes. The difference in latency between the two sites together with the physical difference allows calculation of the motor nerve conduction velocity. A conduction block occurs when the conduction of a nerve action potential is blocked along the path of an intact axon and is usually reliably identified in CMAPs. Conduction block results in a significant drop in CMAP when stimulated proximally compared with the distal stimulation sites.

Sensory Nerve Conduction studies: The sensory nerve action potential is obtained by stimulating the sensory nerve and recording the nerve action potential further down the nerve. Recording sensory nerve action potentials (SNAP) can be orthodromic, which refers to stimulating the nerve distally and recording more proximally. Antidromic testing is the reverse. The latency, amplitude and conduction velocity are measured. Sensory nerve action potentials normally drop in amplitude as the distance increase between the stimulating site and the recording site. Therefore using sensory studies to identify a conduction block may be unreliable.

F waves: allow testing of proximal segments of nerves not normally accessible during routine NCS. When a motor nerve axon is electrically stimulated, an action potential is propagated in both directions away from the initial stimulation site. The distal propagated signal gives rise to the CMAP and an impulse is also conducted proximally to the anterior horn cell causing the axon to backfire. This leads to a small additional muscle depolarisation (F wave) at a longer latency. F waves can be a sensitive indicator of peripheral nerve pathology and can determine the site of conduction slowing.

Peripheral nerve pathology primarily affects axons or myelin. In axonal loss the most striking abnormality is a reduction in CMAP amplitude (fewer functioning axons are connected to

muscle fibres). The conduction velocity and latency may remain normal. The dynamics and timing of an axonal insult will affect the abnormality seen. For example in complete transection the distal CMAP will initially be normal. With loss of myelin the nerve conduction slows. If severe enough, there will be conduction block. Conduction block is the electrophysiological equivalent of neuropraxia and typically offers good prognosis with the best recovery in the shortest period of time.

EMG: The goal of the needle EMG is to examine muscles along the known course of the nerve to identify where the denervation begins and ends. This helps with localisation, for example, the lesion is proximal to the branch supplying the most proximally affected muscle [1]. Despite best efforts, precise localisation is not always possible.

Imaging

MRI is the imaging modality of choice for imaging the spinal canal and the peripheral nerves directly [1]. A high tesla magnet will increase the image resolution of peripheral nerves. T1-weighted images are useful in demonstrating the normal surrounding anatomy and size of the nerve. Fat tissue planes outline the muscles, blood vessels and nerves. Imaging compression or infiltration of a nerve is straightforward, but to detect intrinsic disease of the nerve, T2-weighted images are required with techniques required to eliminate the artifact generated by surrounding fat. The change in size or signal characteristic that results from intrinsic disease of a nerve may be subtle. Furthermore the angle of the tissue plane relative to the magnet will affect the signaling characteristics of the nerve. Comparison with the contralateral side may be useful. The MRI signal characteristics of the muscles supplied by an injured nerve may be of diagnostic value. CT imaging may be appropriate if an acute haematoma is suspected. Ultrasound does not have the image resolution that either MRI or CT but may be of value in certain situations.

Summary and key points

Perioperative peripheral nerve injury is a complex, often multi-factorial outcome that is challenging to manage, investigate and determine cause.

Most serious complications related to regional anaesthesia resolve with time and have a good outcome.

Collaboration with neurologists and other health care professional is essential.

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Before prescribing please review full Product Information available on request from AstraZeneca. NOT FOR INTRAVENOUS ADMINISTRATION UNDER ANY CIRCUMSTANCES

MINIMUM PRODUCT INFORMATION NAROPIN® (ropivacaine hydrochloride). **INDICATIONS & DOSAGE:** Surgical anaesthesia (adults & children >12yrs) Lumbar epidural administration (abdominal, pelvic & lower limb surgery): 0.75% = 15-25mL, 1% = 15-20mL. Caesarean section: 0.75% = 15-20mL. Thoracic epidural administration (upper abdominal & thoracic surgery): 0.75% = 5-15mL. Intrathecal anaesthesia (surgery): 0.5% = 3-4mL. Field block (incl. minor nerve blocks & infiltration): 0.75% = 1-25mL. Major nerve block: 0.75% = 10-40mL. **Analgesia (adults & children >12yrs)** Lumbar epidural administration (Bolus): 0.2% = 10-20mL (Intermittent injections – top up e.g. labour pain management): 0.2% = 10-15mL (minimum interval 30 minutes). (Continuous infusion – incl. labour pain & postoperative pain management): 0.2% = 6-14mL/h. Thoracic epidural administration (continuous infusion for postoperative pain management): 0.2% = 6-14mL/h. Field block (incl. minor nerve blocks & infiltration): 0.2% = 1-100mL. Peripheral nerve block – femoral or interscalene block (continuous infusion or intermittent injections for postoperative pain management): 0.2% = 5-10mL/h. **Wound infusion - adults only (continuous infusion via surgical wound catheter for postoperative pain management): 0.2% = 4-10mL/h up to 48 hours only.* **Analgesia (paediatric patients 0-12yrs)** Caudal epidural administration 0-12yrs (blocks below T12, body weight 2.5-25kg): 0.2% = 1mL. Peripheral nerve block 1-12yrs e.g. ilioinguinal nerve block: 0.5% = 0.4mL. Continuous epidural infusion 31days – 12yrs with body weight 2.5-25kg (31days-6months): bolus 0.2% = 0.5-1mL, infusion up to 72h 0.2% = 0.1mL/kg/h. (6-12months): bolus 0.2% = 0.5-1mL, infusion up to 72h 0.2% = 0.2mL/kg/h. (1-12yrs): bolus 0.2% = 1mL, infusion up to 72h 0.2% = 0.2mL/kg/h. Volume for single epidural block & epidural bolus doses max 25mL in any patient. For all dosage recommendations refer full PI. **CONTRAINDICATIONS:** Hypersensitivity to amide type local anaesthetics; IV administration; uncorrected hypotension; local inflammation, sepsis, septicaemia; IV regional anaesthesia (Bier's block), obstetric paracervical block; general epidural anaesthesia contraindications. **PRECAUTIONS:** RESUSCITATIVE EQUIPMENT & DRUGS SHOULD BE IMMEDIATELY AVAILABLE; INJECT SLOWLY WITH FREQUENT ASPIRATIONS; **POST-MARKETING REPORTS OF CHONDROLYSIS IN PATIENTS RECEIVING POST-OPERATIVE INTRA-ARTICULAR CONTINUOUS INFUSION (UNAPPROVED USE);* patients anti-coagulated or scheduled to be anti-coagulated with low molecular weight heparins & heparinoids; lowest effective dosage used, especially in elderly, debilitated, patients with cardiac conduction impairment, advanced liver disease, severe renal impairment, children 0-12yrs; hypotension, bradycardia; retrobulbar, dental, stellate ganglion blocks; known drug sensitivities; monitor cardiovascular, respiratory function; myasthenia gravis; CNS, spinal cord diseases; large volumes, repeated use; class III anti-arrhythmics; neonates; acute porphyria. Pregnancy (Category B1) & lactation. Use caution with other local anaesthetics & anti-arrhythmic drugs; duration & intensity of block not improved with adrenaline; interacts with alkaline solutions, CYP1A2 inhibitors (e.g. fluvoxamine), CYP3A4 inhibitors (e.g. ketoconazole); CYP2E1 (e.g. cimetidine) – theoretical. **ADVERSE REACTIONS:** *Very common:* hypotension, nausea. *Common:* bradycardia, hypertension, tachycardia, paraesthesia, temperature elevation, rigors, headache, dizziness, vomiting, urinary retention, back pain, insomnia, chest pain, pain, oliguria. For all other adverse events refer to full PI. Date of TGA approval: 13 April 2011.

References: 1. Naropin® Approved Product Information.

*Please note changes in Product Information

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Duratocin®
carbetocin

Single injection for lasting prevention

DURATOCIN® for lasting prevention of postpartum haemorrhage following elective caesarean section under epidural or spinal anaesthesia[1,2,3]

DURATOCIN® INJECTION, 5 x 1mL
Contains carbetocin 100µg/mL
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LONG ACTING

- Long-acting oxytocin agonist – half-life at least FOUR times longer than oxytocin[2]

RAPID ONSET

- Rapidly returns uterine tone – achieved within TWO minutes[3,4]

EFFECTIVE

- As effective as continuous oxytocin infusion in maintaining uterine tone and preventing excessive intra-operative blood loss[1,3]
- Results in less additional uterotonic interventions required compared to continuous oxytocin infusion[2,3]

GOOD SAFETY PROFILE

- Similar to oxytocin[1,2,3]

CONVENIENT

- Available as a simple, convenient, single-dose intravenous injection, eliminating the need for infusion[1,3]

Minimum Product Information

DURATOCIN® (Carbetocin Injection): INDICATIONS: DURATOCIN is indicated for the prevention of uterine atony and excessive bleeding following delivery of the infant by elective caesarean section under epidural or spinal anaesthesia. DURATOCIN is an oxytocic that reduces the need for additional oxytocics. Duratocin has not been studied in women at high risk of postpartum haemorrhage, for example with parity greater than 4, with hypertension, following especially prolonged labour, or with general anaesthesia. **DOSAGE AND ADMINISTRATION:** A single intravenous dose of 100µg (1 mL) of DURATOCIN (carbetocin injection) is administered by bolus injection, slowly over 1 minute, only when delivery of the infant has been completed by caesarean section under epidural or spinal anaesthesia. DURATOCIN can be administered either before or after delivery of the placenta. DURATOCIN is to be used as a single dose only. **CONTRAINDICATIONS:** Because of its long duration of action relative to oxytocin, uterine contractions produced by carbetocin cannot be stopped by simply discontinuing the medication. Therefore carbetocin should not be administered prior to delivery of the infant for any reason, including elective or medical induction of labour. Inappropriate use of carbetocin during pregnancy could theoretically mimic the symptoms of oxytocin overdosage, including hyperstimulation of the uterus with strong (hypertonic) or prolonged (tetanic) contractions, tumultuous labour, uterine rupture, cervical and vaginal lacerations, postpartum haemorrhage, utero-placental hypoperfusion and variable deceleration of foetal heart, foetal hypoxia, hypercapnia, or death. Carbetocin should not be used in patients with a history of hypersensitivity to oxytocin or carbetocin. Carbetocin should not be used in patients with vascular disease, especially coronary artery disease, except with extreme caution. Carbetocin is not intended for use in children. **PRECAUTIONS:** Some patients may not have an adequate uterine contraction after a single injection of DURATOCIN (carbetocin injection). In these patients, administration of DURATOCIN should not be repeated and more aggressive treatment with additional doses of other available uterotonic drugs like oxytocin or ergometrine is warranted. In cases of persistent bleeding, the presence of retained placental fragments, coagulopathy, or trauma to the genital tract should be ruled out. DURATOCIN is currently not indicated in emergency caesarean section or after vaginal delivery. DURATOCIN is not recommended for use in elderly patients. Although no cases of partial retention or trapping of the placenta have been reported, this remains a theoretical possibility if the drug is administered before delivery of the placenta. Significant antidiuretic effect is not anticipated and has not been demonstrated at the recommended dose but, as carbetocin is closely related in structure to oxytocin, hyponatraemia and water intoxication should be considered in relevant clinical situations. Carbetocin should be used cautiously in the presence of epilepsy, migraine, asthma or any state in which a rapid addition to extracellular water may produce hazard for an already overburdened system. Patients with eclampsia and pre-eclampsia should be monitored for changes in blood pressure. **ADVERSE REACTIONS:** The adverse events observed with carbetocin during the clinical trials were of the same type and frequency as the adverse events observed with oxytocin when administered after caesarean section under epidural or spinal anaesthesia. Intravenous carbetocin was frequently (10-40% of patients) associated with nausea, abdominal pain, pruritis, flushing, vomiting, feeling of warmth, hypotension, headache and tremor. As most of these reactions also occurred in patients treated with placebo, it is likely that many were associated with caesarean section, spinal or epidural anaesthesia or drugs used during the procedure. Infrequent adverse events (1-5% of patients) included back pain, dizziness, metallic taste, anaemia, sweating, chest pain, dyspnoea, chills, tachycardia and anxiety. Please refer to the Approved Product Information for events reported in clinical studies. Approved PI last amended Oct 2007 available from Ferring Pharmaceuticals.

PBS Information: This product is not listed on the PBS.

Please consult Product Information before prescribing. Approved Product Information accompanies this item.

References: 1. Boucher, M et al. J Perinatol 1998; 18:202 **2.** Dansereau, J et al. Am J Obstet Gynecol 1999, 180:670-6 **3.** DURATOCIN® Product Information **4.** Hunter DJS et al. Clin Pharmacol Ther 1992; 52:60-7

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Duratocin® carbetocin

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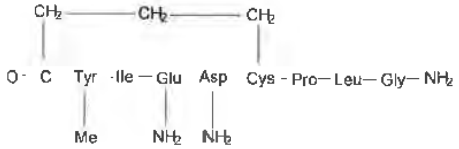
DURATOCIN®
(Carbetocin Injection)

NAME OF THE DRUG
Carbetocin

Synonyms:
2,1-Desamino-4, 1-desthio-O4, 2-Methyl 1 [1-homocysteine] oxytocin
1-desamino-1-monocarba-2-(0-methyl)-tyrosine-oxytocin
(2-0-methyltyrosine)-1-deaminocarba-1-oxytocin
(6,1-β deaminocystathionine, 2-0-methyl-tyrosine)-oxytocin
[Tyr(Me)^2]-desamino-1-carba-oxytocin

CAS: 37025-55-1

Structure:



Molecular Formula: $C_{45}H_{69}N_{11}O_{12}S$ **Molecular Weight:** 988.1

DESCRIPTION
Carbetocin is a white, fluffy lyophilized powder, soluble in water, ethanol, methanol and acetic acid. Carbetocin is insoluble in ether and petroleum ether.
Each ampoule contains 100µg of carbetocin, 9 mg sodium chloride, acetic acid – glacial to pH 3.8 and water for injections to 1 mL.

PHARMACOLOGY
DURATOCIN (carbetocin injection) is a long-acting synthetic octapeptide analogue of oxytocin with agonist properties. It can be administered intravenously as a single dose immediately following delivery by caesarean section under epidural or spinal anaesthesia, to prevent uterine atony and postpartum haemorrhage.
The clinical and pharmacological properties of carbetocin are similar to those of naturally occurring oxytocin, another posterior pituitary hormone. In in vitro studies, carbetocin was shown to bind to the oxytocin receptor with similar affinity as the natural peptide. Carbetocin elicited similar uteronic and galactogogic effects to oxytocin in animals and in vitro. Carbetocin was less potent than oxytocin, but its action was more prolonged. The oxytocin receptor content of the uterus is very low in the non-pregnant state, and increases during pregnancy, reaching a peak at the time of delivery. Therefore carbetocin has no effect on the non-pregnant uterus, and has a potent uterotonic effect on the pregnant and immediate postpartum uterus.
The onset of uterine contraction following carbetocin administration by either the intravenous or intramuscular route is rapid, with a firm contraction being obtained within 2 minutes in around 90% of patients. The total duration of action of a single intravenous injection of carbetocin on uterine activity is about one hour suggesting that carbetocin may act long enough to prevent postpartum haemorrhage in the immediate postpartum period. In comparison to oxytocin, carbetocin induces a prolonged uterine response when administered postpartum, in terms of both amplitude and frequency of contractions.

Carbetocin, when administered immediately postpartum as a single intravenous bolus injection of 100µg to women delivered by caesarean section under epidural or spinal anaesthesia, was found to be significantly more effective than placebo, as evidenced by the need for additional oxytocin therapy in the operating room.
Carbetocin administration also appears to enhance uterine involution in the early postpartum period, as evidenced by the repeated measurement of the uterine fundus.

Pharmacokinetics
The distribution and elimination half-lives of carbetocin in 25 non-pregnant women were found to be 5.5 ± 1.6 minutes and 41 ± 11.9 minutes respectively after a 400µg intravenous dose, indicating a lack of dose-dependency for this parameter. The clearance of carbetocin from the body (both total and renal), and the volume of distribution do not appear to be dose dependent, whereas Cmax and $AUC_{0-\infty}$ show proportional changes with increasing dose.

Approximately 0.7% of the carbetocin dose is eliminated in the unchanged form by the kidney, indicating that carbetocin, like oxytocin, is eliminated primarily by non-renal routes.

CLINICAL TRIALS:
Two large double blind trials were conducted using carbetocin.

A Randomised Parallel group, Double-blind, placebo-controlled multicentre clinical trial to evaluate the safety and efficacy of a single dose of carbetocin to control uterine bleeding after elective caesarean section.

Inclusion Criteria:

Women undergoing elective caesarean section under epidural anaesthesia, without a history of heart disease, hypertension, cardiac arrhythmia or evidence of liver, renal or endocrine disease, who gave informed consent.

Primary Efficacy variable:

The incidence of further oxytocic therapy following test drug administration.

Treatment Group	No. Patients Randomised (Evaluable)	Efficacy Results: Patients requiring further oxytocic therapy	Safety Results: Serious Adverse Events
Carbetocin 100µg (single IV injection)	64 (62)	8	0
Placebo (IV injection)	58 (57)	41	0

Summary:

When given as a single bolus intravenous dose of 100µg after delivery of the infant by elective caesarean section under epidural, carbetocin was found to be significantly more effective than placebo in preventing the clinician assessed need for additional oxytocin therapy with only 13% of patients requiring intervention with further oxytocic therapy compared to 72% of patients in the placebo group (p=0.001). There were no serious or unexpected adverse events and no patient dropped out of the study due to safety concerns. There was an increased incidence of the following adverse events in the carbetocin group vs the placebo group; Flushing (34% vs 10%, p =0.002), abdominal pain (27% vs 10%, p =0.02), pruritus (48% vs 31%, p=0.05). The overall incidence of nausea during the study was not significantly different between the groups but was higher in the carbetocin group whilst the patient was in the operating room (36% vs 17%, $p < 0.05$). There was no significant difference between the groups for other adverse events reported.

A Randomised Parallel group, Double-blind, Double-dummy, multicentre clinical trial to evaluate the safety and efficacy of a single dose of carbetocin vs 8 hours oxytocin infusion after caesarean section in maintaining adequate uterine contraction after caesarean section.

Inclusion Criteria:

Healthy women undergoing elective caesarean section under epidural anaesthesia, who gave written informed consent.

Primary Efficacy variable:

The incidence of further oxytocic therapy following test drug administration.

Treatment Group	No. Patients Randomised (Evaluable)	Efficacy Results: Patients requiring further oxytocic therapy	Safety Results: Serious Adverse Events
Carbetocin 100µg (single IV injection)	348 (317)	15	4
Oxytocin: 5IU bolus + 8 hours 20IU IV infusion	346 (318)	32	4

Summary:

When given as a single intravenous dose of 100µg, carbetocin was associated with lower incidence of "need for additional oxytocic intervention" when compared to an 8 hour oxytocin infusion: such intervention occurred in 15 (5%) of patients receiving carbetocin compared to 32 (10%) of patients administered oxytocin. Odds of intervention were 2.0 times lower for carbetocin vs oxytocin (p=0.031).
There were no significant differences in the frequency of adverse events between treatment groups. Four serious or unexpected adverse events occurred in each group.

The dose-response relationship of carbetocin and uterine contraction was evaluated in a clinical trial involving 18 patients. Here the intravenous dose of carbetocin required to produce sustained tetanic contraction after caesarean section was determined. Although 11 of 12 women responded with adequate uterine contraction to total doses of 30-90µg carbetocin, none was considered to have adequate response to a starting dose less than 60µg. All 6 women given 100µg had an adequate uterine contraction although one did not satisfy the response criteria of the study. A single 100µg intravenous injection was therefore selected for clinical use.

In a trial in 57 women undergoing elective caesarean section under epidural anaesthesia, carbetocin was compared to oxytocin for its ability to reduce intraoperative blood loss. A single 100µg injection of carbetocin was compared to oxytocin (total dose 32.5 IU).
It was found that a single intravenous bolus injection of carbetocin was at least as effective as 16 hours of continuous oxytocin infusion, in terms of efficacy in maintaining uterine contraction after caesarean section, and in preventing excessive intraoperative blood loss following caesarean delivery. This study confirmed the ability of a 100µg intravenous dose of carbetocin to maintain adequate uterine tone after caesarean section.
Carbetocin also appeared to accelerate the initial stages of uterine involution, associated with the return of the uterus to the non-pregnant size and position.

DURATOCIN has not been studied in cases involving emergency caesarean section, classical caesarean section, anaesthesia other than epidural or spinal, or in patients presenting significant heart disease, history of hypertension, known coagulopathy or evidence of liver, renal or endocrine disease (excluding gestational diabetes). Appropriate studies have not been undertaken and doses established in women following labour or vaginal delivery.

INDICATIONS

DURATOCIN is indicated for the prevention of uterine atony and excessive bleeding following delivery of the infant by elective caesarean section under epidural or spinal anaesthesia. DURATOCIN is an oxytocic that reduces the need for additional oxytocics.
Duratocin has not been studied in women at high risk of postpartum haemorrhage, for example with parity greater than 4, with hypertension, following labour especially prolonged labour, or with general anaesthesia.

CONTRAINDICATIONS

Because of its long duration of action relative to oxytocin, uterine contractions produced by carbetocin cannot be stopped by simply discontinuing the medication. Therefore carbetocin should not be administered prior to delivery of the infant for any reason, including elective or medical induction of labour. Inappropriate use of carbetocin during pregnancy could theoretically mimic the symptoms of oxytocin overdosage, including hyperstimulation of the uterus with strong (hypertonic) or prolonged (tetanic) contractions, tumultuous labour, uterine rupture, cervical and vaginal lacerations, postpartum haemorrhage, utero-placental hypoperfusion and variable deceleration of foetal heart, foetal hypoxia, hypercapnia, or death.
Carbetocin should not be used in patients with a history of hypersensitivity to oxytocin or carbetocin.
Carbetocin should not be used in patients with vascular disease, especially coronary artery disease, except with extreme caution.
Carbetocin is not intended for use in children.

PRECAUTIONS

Some patients may not have an adequate uterine contraction after a single injection of DURATOCIN (carbetocin injection). In these patients, administration of DURATOCIN should not be repeated and more aggressive treatment with additional doses of other available uterotonic drugs like oxytocin or ergometrine is warranted. In cases of persistent bleeding, the presence of retained placental fragments, coagulopathy, or trauma to the genital tract should be ruled out.
DURATOCIN is currently not indicated in emergency caesarean section or after vaginal delivery.
DURATOCIN is not recommended for use in elderly patients.
Although no cases of partial retention or trapping of the placenta have been reported, this remains a theoretical possibility if the drug is administered before delivery of the placenta.
Significant antidiuretic effect is not anticipated and has not been demonstrated at the recommended dose but, as carbetocin is closely related in structure to oxytocin, hyponatraemia and water intoxication should be considered in relevant clinical situations.
Carbetocin should be used cautiously in the presence of epilepsy, migraine, asthma or any state in which a rapid addition to extracellular water may produce hazard for an already overburdened system.
Patients with eclampsia and pre-eclampsia should be monitored for changes in blood pressure.

Carcinogenicity/Mutagencicity:
No long term studies in animals have been performed to evaluate the carcinogenic potential of carbetocin.
Carbetocin was not genotoxic in assays for gene mutation (in vitro bacterial and mouse lymphoma cell assays) and chromosomal damage (human lymphocytes in vitro and mouse micronucleus test in vivo).

Use in Pregnancy:
Category C. Carbetocin induces uterine contraction and may cause premature or hypertonic labour. Therefore, DURATOCIN (carbetocin injection) use during pregnancy is contraindicated (see CONTRAINDICATIONS).

Use in Lactation:
Small amounts of carbetocin have been shown to cross over from plasma into the breast milk of nursing women who were given a 70µg dose intramuscularly, between 7 and 14 weeks postpartum. The mean peak concentration in breast milk was approximately 50 times lower than in plasma, and the ratio of the milk to plasma area under the concentration versus time curves (M/P_{AUC}) was only 2-3%. The small amount of carbetocin transferred into breast milk or colostrum after a single injection, and subsequently ingested by a breast feeding infant, would not be expected to present a significant safety concern. This is due to the fact that carbetocin would be rapidly degraded by peptidases in the infant gastrointestinal tract.
Oxytocin is known to cause contraction of the myoepithelial cells surrounding the mammary alveoli, thereby stimulating milk let-down. There is no sufficient evidence to determine whether carbetocin can also stimulate milk let-down.
However, milk let-down was found to occur normally in 5 nursing women after receiving a 70µg carbetocin dose by the intramuscular route.
In a pilot postnatal development study, administration of IV doses ≥ 0.01 mg/kg/day (similar to the clinical dose based on body surface area) to lactating rats was associated with impaired pup growth.
A no-effect-dose was not determined.

Interactions with other drugs:
No specific drug interactions have been reported with carbetocin. However, since carbetocin is closely related in structure to oxytocin, it is possible that some of the same drug interactions could occur. Severe hypertension has been reported when oxytocin was given 3-4 hours following prophylactic administration of a vasoconstrictor in conjunction with caudal block anaesthesia.

Effects on Ability to Drive and Use Machines: Not applicable.

ADVERSE REACTIONS

The adverse events observed with carbetocin during the clinical trials were of the same type and frequency as the adverse events observed with oxytocin when administered after caesarean section under epidural or spinal anaesthesia.
Intravenous carbetocin was frequently (10-40% of patients) associated with nausea, abdominal pain, pruritus, flushing, vomiting, feeling of warmth, hypotension, headache and tremor.
As most of these reactions also occurred in patients treated with placebo, it is likely that many were associated with caesarean section, spinal or epidural anaesthesia or drugs used during the procedure.

In a 122 patient placebo controlled study, the adverse events occurring in >5% of women are presented in Table 1, below.

Table.1

Adverse Event	Carbetocin (n=64)	Placebo (n=58)	Statistical Significance
	%	%	
Nausea	61	57	NS
Pruritus	48	31	*
Hypotension	45	38	NS
Vomiting	41	36	NS
Flushing	34	10	*
Abdominal pain	27	10	*
Feeling of warmth	19	10	NS
Anaemia	17	21	NS
Tremors	16	17	NS
Back Pain	13	7	NS
Dizziness	13	7	NS
Incisional abnormality	11	12	NS
Headache	9	16	NS
Sweating	8	0	NS
Fever	6	5	NS
Tachycardia	5	5	NS
Insomnia	3	7	NS
Chills	3	5	NS
Metallic Taste	2	5	NS
Paraesthesia	0	5	NS

NS = Not Significant, * $p \leq 0.05$

Infrequent adverse events (1-5% of patients) included back pain, dizziness, metallic taste, anaemia, sweating, chest pain, dyspnoea, chills, tachycardia and anxiety.

DOSAGE AND ADMINISTRATION

A single intravenous dose of 100µg (1 mL) of DURATOCIN (carbetocin injection) is administered by bolus injection, slowly over 1 minute, only when delivery of the infant has been completed by caesarean section under epidural or spinal anaesthesia. DURATOCIN can be administered either before or after delivery of the placenta. DURATOCIN is to be used as a single dose only.

OVERDOSAGE

Overdosage of carbetocin can be expected to produce enhanced pharmacological effects. Therefore, when carbetocin is administered postpartum, overdosage may be associated with uterine hyperactivity and pain. Treatment consists of symptomatic and supportive management.

PRESENTATION

DURATOCIN is a ready-for-use solution containing 100µg carbetocin in a 1 mL clear glass ampoule with a white identification ring and a blue dot indicating the cut area. Each pack contains 5 ampoules.

Storage: DURATOCIN is stable for 2 years from date of manufacture when stored at 2-8°C (Refrigerate. Do not freeze.) and protected from light. Once the ampoule has been opened, the product should be used immediately.

NAME AND ADDRESS OF THE SPONSOR

Ferring Pharmaceuticals Pty Ltd
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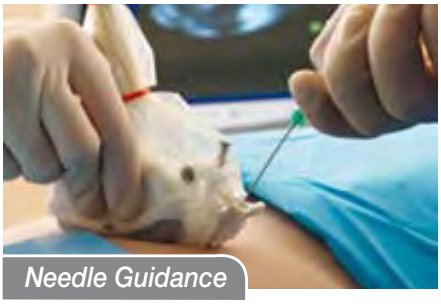


Needle Guidance

- Needle Guidance Systems for Ultrasound-Guided Procedures

Cleaning Solutions & Print Media

- Disinfectants & Cleaners • Gels
- Printers, Print Media & Supplies

WHY USE CIVCO PRODUCTS?

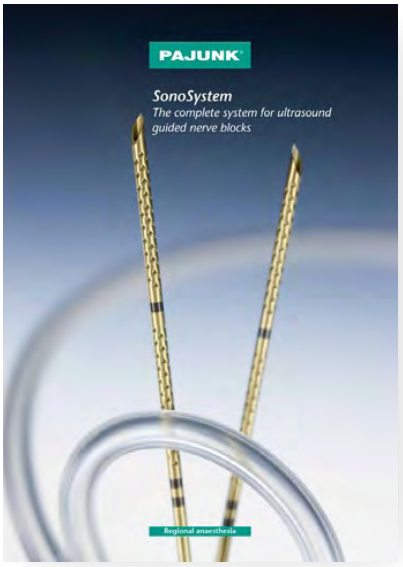
- *Disposable design reduces risks of cross-contamination and increases patient throughput, cost effectively*
- *Enhanced accuracy ensuring needle tracks within the plane of the sonographic image*
- *Improving storage and protection of your valuable transducers*

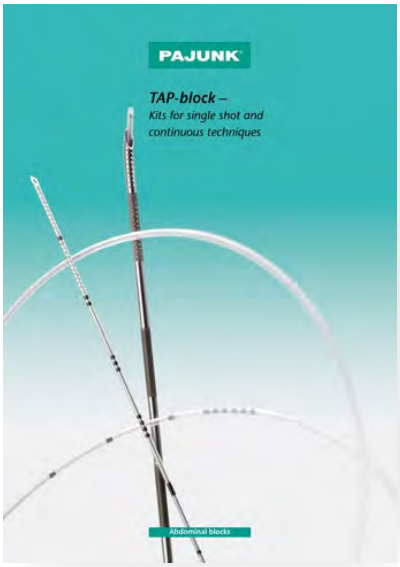
Whichever your speciality, we offer broad solutions and product lines for Urology, Intra-Operative Ultrasound, Regional Anesthesia, Interventional Radiology, Cardiology, Women's Health, Emergency Medicine and Vascular.

For further information on any of the products, please contact your Civco account representative

*telephone **03 9879 6200** / email info@meditron.com.au / www.meditron.com.au*

SURIMEX
Surgical Import Export Distributor



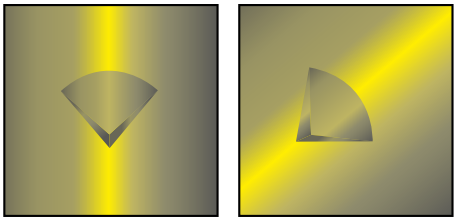


SonoSystem

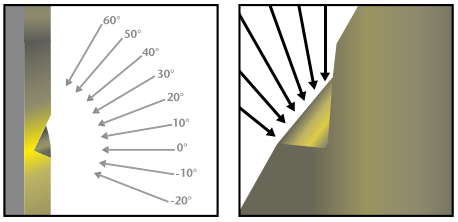
The complete system for ultrasound guided nerve blocks

The method of ultrasound monitoring is increasingly gaining importance in regional anaesthesia. Today even the finest anatomical structures including peripheral nerves can be identified in detail and anaesthetised selectively under viewing using modern high-resolution ultrasound scanners. This method supports the traditional procedure by means of nerve stimulation. Daily practice has shown that it is not that easy to identify the cannula tip definitely and clearly, on the viewing screen of the ultrasonic device. Before this background, PAJUNK® has developed the "Cornerstone" reflectors in co-operation with Dr Chris Mitchell and has thereby launched a new cannula generation, with a reflection guarantee under ultrasound monitoring. Products available with this ultrasound design include stimulating and non-stimulating needles. These versions are also available in kits.

Ultrasound marker with reflection guarantee

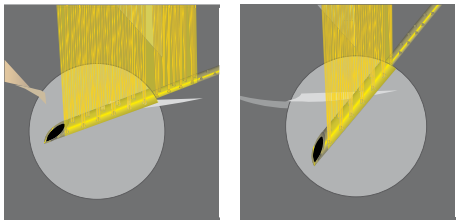


The "Cornerstone" reflectors developed by Dr Chris Mitchell are structured so that all ultrasound waves are reflected without losses.



➡ This provides optimal visibility of the cannula tip and it can be identified with absolute certainty.

Visibility – regardless of the puncture angle



The nature of the "Cornerstone" reflectors renders optimal reflection properties.

➡ The reflective behaviour at this optimal performance level is warranted at steep puncture angles, and at flat puncture angle as well.

Needle developer Chris Mitchell will be speaking on Saturday 10th March at 14:30, make sure you dont miss out.

For more information please visit our booth (12) at the ASURA conference

www.surimex.com.au

ambIT®

Superior pain management

The ambIT® Infusion System - Superior Pain Management

The innovative ambIT® PCA (Patient Controlled Analgesia) infusion pump provides a simple yet sophisticated solution for all types of post-operative pain management.

Continuous Regional Nerve Blocks and Surgical Site Infusions

The ambIT® system is well suited for ambulatory pain management and has several advantages in comparison to elastomeric infusion devices for regional nerve blocks and surgical site infusions.

Numerous clinical trials have demonstrated that the ambIT® can safely administer accurate dosages of local anaesthetic into regional nerve and surgical sites, with high levels of satisfaction from both patients and clinicians.

Visit us at Booth 10
for a demonstration and clinical update

The ambIT® offers increased **safety and accuracy**

- Flow occlusion and flow accuracy alarms.
- Higher levels of accuracy than elastomeric devices – ambIT has accuracy of + or – 6% where elastomeric devices can exhibit up to + or – 25%.
- Allows for an accurate measure of medication delivered. Monitoring of elastomeric devices rely on subjective judgment.

The ambIT® offers increased **flexibility and mobility**

- Ability to program bolus/lockout and continuous flow rates.
- Ability for a clinician to titrate dosages based on history reports.
- Compact design and carry bag allow patients to mobilise and be candidates for early discharge.

ALLIED MEDICAL

For more information call customer service on 1300 550 310

GE Healthcare

Crystal clear sight for procedures

Needle-guided procedures require precision. LOGIQ *e* and Venue 40 provide this "always on" feature that accurately reveals the structure of a needle within anatomy, without distortion of the needle. You can see the needle advance in real time, with no image processing delays.

Our Needle Recognition harnesses pattern-recognition technology, which is seamlessly integrated with our proprietary B-Steer + and CrossXBeam*features to further enhance definition of needle and anatomy.

LOGIQ *e*

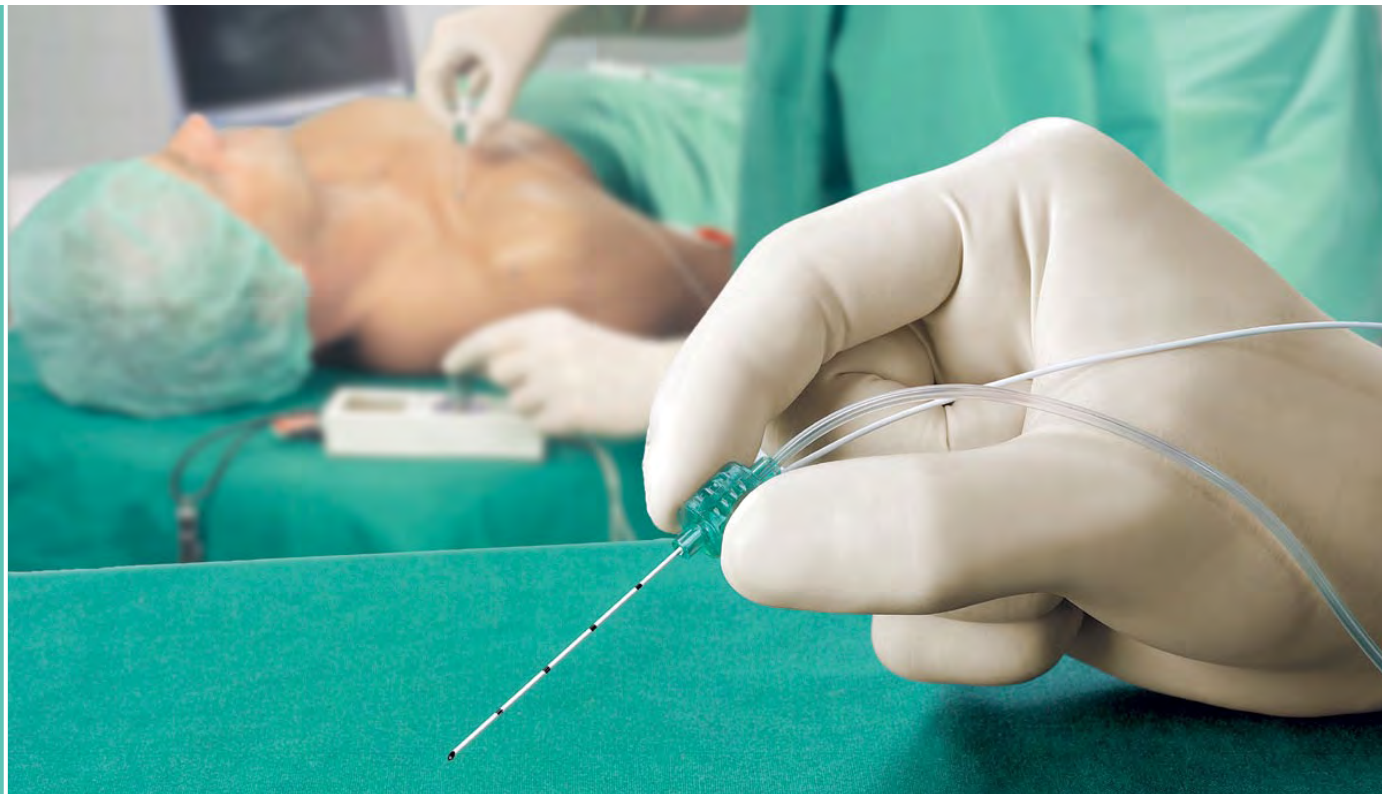
Venue 40

imagination at work

DOC1106480

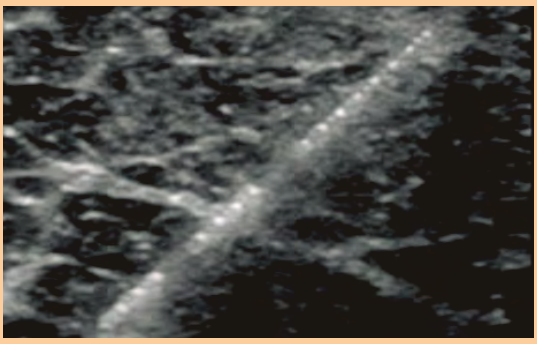
Stimuplex Ultra

The **Ultra**sound Visible Peripheral Nerve Block Needle



Stimuplex Ultra provides:

- **Visibility:** Echogenic laser markings facilitate precise needle visualisation
- **Safety:** Distinct Ultra-pattern with safety code for more confidence
- **Ease:** Ultrasound reflectors at multiple sites for easy needle detection from different angles
- **Feel:** Short Stimuplex bevel with excellent needle puncture and gliding characteristics



The Ultra-pattern consists of three segments of ultrasound reflectors. The safety code **"short-short-long"** distinguishes the needle tip from the upper needle shaft.

Each of the two short segments represent approximately 5mm and the long segment 10mm. The two short segments must be visualised to confirm the needle tip location.

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VOLUVEN®

6% HydroxyEthylStarch 130/0.4

FRESENIUS KABI

VOLUVEN® MINIMUM PRODUCT INFORMATION

VOLUVEN® 6% Solution for Infusion (60g/L Hydroxyethyl Starch 130/0.4 and 9g/L Sodium Chloride). INDICATIONS: Therapy and prophylaxis of hypovolaemia. CONTRAINDICATIONS: Fluid overload (hyperhydration), especially with pulmonary oedema and congestive cardiac failure; renal failure with oliguria or anuria; patients receiving dialysis treatment; intracranial bleeding; severe hypernatraemia or severe hyperchloraemia; known hypersensitivity to hydroxyethyl starches. PRECAUTIONS: Fluid overload caused by overdose particularly with cardiac insufficiency or severe kidney dysfunctions. For severe dehydration, a crystalloid solution should first be given. Severe liver disease or bleeding disorders eg von Willebrand's disease. Supply sufficient fluid and regularly monitor kidney function, fluid balance and serum electrolytes. ADVERSE EFFECTS: Rarely anaphylactoid reactions (hypersensitivity, mild-influenza-like symptoms, bradycardia, tachycardia, bronchospasm, non-cardiac pulmonary oedema); pruritis; increase in concentration of serum amylase; at high doses dilution effects may result in corresponding dilution of blood components such as coagulation factors, plasma proteins and decrease in haematocrit, and rarely disturbances in blood coagulation DOSAGE AND ADMINISTRATION: Initial 10-20mL infused slowly. Daily dose and rate of infusion depend on patient's blood loss, maintenance or restoration of haemodynamics and haemodilution. *Up to 50mL of Voluven per kg of body weight per day (equivalent to 3g hydroxyethyl starch and 7.7 mmol sodium per kg of body weight). This dose is equivalent to 3500mL of Voluven for a 70kg patient. The majority of clinical trial data stem from a maximal dose of up to 33mL/kg/day. Hepatic and renal monitoring is necessary at higher doses. Based on TGA Approved Product Information dated 8th June 2010. PBS Dispensed price (3 bags) $45.75. Fresenius Kabi Australia Pty Limited 964 Pacific Highway PYMBLE NSW 2073 www.fresenius-kabi.com.au PM2011.049

Before prescribing please review Product Information available on request from Fresenius Kabi Australia Pty Limited.

PBS Information : This product is listed on the PBS for therapy and prophylaxis of hypovolaemia.