Needles used for spinal anesthesia

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Since the discovery of spinal anesthesia in 1885 by J Leonard Corning, spinal needles have been modified to simplify their use and minimize complications. Needle design variables, such as diameter, tip design and orifice location, have been altered to enable rapid flow of cerebral spinal fluid (CSF) and injected medications, yet simultaneously limit dural trauma and loss of CSF. CSF loss can result in a severe postdural puncture headache (PDPH). Blunt pencil-point tip needles have been observed to cause a lower incidence of PDPH than similar sized sharp, cutting tip needles. Smaller diameter needles are also associated with a lower incidence of PDPH. A recent alteration in spinal needles is not to the needle per se, but rather the microcatheters placed through them; currently used in Europe, such catheters are again being evaluated in the USA. Further advancements in spinal needles will most likely involve some of the design elements previously altered, as well as new features not yet recognized as important at this time.

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"Searing and spreading like hot molten metal, the head pain was all consuming, the lights surreal and too bright, and the only sound that I could hear through the ringing wooliness was my own screaming. My head. Please help me…"[1].

Seemingly lifted from a medieval text on pain and suffering, this contemporary account is from a previously healthy patient who underwent a spinal puncture for the pain relief during childbirth. The resulting headache, termed a postdural puncture headache (PDPH) from the hole created in the dural tissues, is produced through a loss of cerebral spinal fluid (CSF) and subsequent tension on meningeal structures; when severe, the treatment of choice is the injection of the patient's own blood into the epidural space forming a patch over the dural puncture, that is, an epidural blood patch (EBP). The incidence of PDPH, as well as the ability to safely and reliably perform the technical aspects of a dural puncture, is directly related to the design of the spinal needle. This review will focus on the design modifications made to spinal needles to maximize their clinical utility and minimize their side effects.

Early needles & the hypodermic syringe

Although the discovery of spinal anesthesia in 1885 is credited to the New York neurologist J Leonard Corning, the achievement was dependent on the development of needles, and more specifically, needles that could be attached to syringes (TABLE 1). Termed a hypodermic needle in 1859 (Greek origin: 'hypo', meaning under and derma, meaning skin), the original hollow needle was designed to penetrate the skin to deposit medications in the subcutaneous tissues; with the attachment of a syringe, that is, a hypodermic syringe, the potential usefulness was increased significantly. The idea of introducing medications into the body via tubular devices was not new; Sir Christopher Wren, the celebrated English architect, together with the chemist Robert Boyle injected liquid (wine) into a vein using a goose quill and a pig bladder in 1659. The early experiments with these devices, however, depended on the surgical opening of vessels or body cavities; this dramatically changed with the introduction of the hollow needle (cannula and retractable trocar) by the Irish surgeon Francis Rynd in 1845. Rynd initially attached his needle to a tube for drip infusions via

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gravity and later added a syringe; although his use of a syringe and needle together is believed to predate the work of others, he did not publish the design of his syringe until 1861. In 1855, the French veterinary surgeon Charles Gabriel Prabaz developed and published his work with a needle attached to a metal calibrated syringe. Independently in the same year, the Scottish physician Alexander Wood attached a syringe to a hollow needle with a sharpened end developed in 1853 by the English chemist Daniel Ferguson [2]. The combination of a needle and syringe enabled the subsequent development of needles specifically for the purpose of entering the spinal (intrathecal or subarachnoid) space for collecting CSF and providing analgesia or anesthesia.

Spinal needles

Following the demonstration of spinal anesthesia by Corning, a number of refinements to the spinal needle have been made. Although changes were often made simultaneously, these developments will be reviewed in four basic categories: diameter size, tip point, orifice location and materials.

Needle diameter

The nomenclature for needles derives from the Standard Wire Gauge (SWG), a guide used to measure electrical wires. The SWG is not a defined unit of measurement, such as an inch or millimeter, but rather a comparative standard of a defined set of sizes or thicknesses. Currently accepted gauges were standardized using measuring instruments developed by Holzapffel and Stubs in 1847; their work described gauge measurements in inches [3]. As a close approximation, gauges are multiples of 4/1000 of an inch, with an increase in gauge representing a decrease in diameter. Spinal needles in common use today are 22–27 G, but are available in sizes ranging from 19 to 30 G. By contrast epidural needles are commonly 16–18 G. Needle sizes are identified by a number, the gauge symbol (G) and a fraction indicating the length. An example is 28 G 1/2, which means a 28 G needle that is a half inch in length.

The needles introduced prior to Corning have limited descriptions, particularly with regards to their diameter, as formal acceptance of the gauge system in many countries, including the USA and the UK, did not occur until the 1870–1880s [3]. Early needles were often used with larger diameter introducer needles, which were used to puncture the skin and support the early course of the spinal needle through the subcutaneous tissues and ligaments. In 1891, a report by Heinrich Irenaeus Quincke used a sharp, bevelled hollow needle to obtain CSF in a standardized method [4]. August Karl Gustav Bier, using the same Quincke needle in 1899, reported the successful use of cocaine spinal anesthesia for lower limb surgery in six patients. Noting that cumbersome introducers and dilators were required for the spinal placement of the fine needle, Bier designed a larger bore needle (most likely 15 or 17 G) in 1899, which needed no introducer (FIGURE 1). A gradual movement away from larger needles occurred as more investigators recognized the possibility of greater dural trauma causing loss of anesthetic solutions and a greater incidence of PDPH. Sicard recognized in 1898 that the PDPH was most likely caused by a loss of CSF [1], although the relationship between needle diameter and CSF loss was not given much discussion until Barker developed an 18 or 19 G needle in 1907, and Babcock developed a design similar to the original Corning needle but with a 20 G diameter in 1914. Referred to as the Quincke-Babcock needle, the design became the standard needle (FIGURE 1). A return to the two-needle technique (shorter, larger diameter introducer needle and a longer, smaller diameter needle for dural puncture) was advocated by Hoyt in 1922 as a possible way of creating less trauma to the dura [1]. This theory was realized in 1923 by Herbert Merton Greene, who evaluated dural holes created by different needle sizes and tips, and stated that smaller, less traumatic holes were the result of smaller needles with a rounded tip [1]. He developed a 23 G needle, also in 1923, which was later modified by Barnett A Greene in 1950 to a 26 G needle passed through a 21 G introducer.

Table 1.

Timeline	Inventor	Needle description	Novel development
1841	Z Jayne	Syringe with a small, sharp, hollow beak with an opening	Syringe with a sharp tip orifice
1845	F Rynd	Hollow metal cannula with trochar	First hollow 'needle'; used with a retractable trochar and a 'drip' tube for injection by gravity
1853	D Ferguson	Platinum needle with trochar	Sharpened end with an oblique opening
1853	A Wood	Needle with syringe	First use of a syringe with a needle; later added a syringe with graduated markings and a smaller needle
1855	CG Prabaz	Needle with syringe	First syringe (metal) with a screw driven piston to provide a specific dose
1885	JL Corning	Gold or platina needle with a flexible cannula and a sharp, short cutting bevel	First spinal anesthetic; used with a short introducer with a right angled handle

Table 1.

Timeline	Inventor	Needle description	Novel development
1891	H Quincke	Needle with sharp bevel	First standardized technique of lumbar puncture for the release of cerebrospinal fluid
1898	AK Bier	Quincke needle used to provide spinal anesthesia in a series of patients	First series of spinal anesthesia for surgical procedures; association with severe headaches observed
1899	AK Bier	Larger bore needle (15 or 17 G) with a long, sharp, cutting bevel	Return to a larger needle to enable use without an introducer
1900	WS Bainbridge	Flexible metal needle with a small circular hub, a short, sharp cutting bevel and a stylet with a matching bevel. Attached to a metal syringe	Proposed to cause less pain on insertion
1907	AE Barker	Needle (18 or 19 G) with a 1 mm longer inner, blunt tipped needle for injection (later replaced by solid stylet)	First use of longer inner needle for injection, later a solid stylet
1914	WW Babcock	Iridised platinum or gold needle (20 G) with medium length, sharp bevel with matching stylet	Even smaller needle, became a popular needle
1921	G Labat	Unbreakable nickel needle with short, sharp bevel with matching stylet	
1922	R Hoyt	Two-needle technique with a sharp, large bore outer needle for skin penetration and a longer finer inner needle for dural puncture	Return to introducer plus needle technique; proposed the smaller dural puncture caused lower incidence of postdural puncture headache
1923	HM Greene	Needle (23 G) with a medium length, blunted bevel with matching stylet	First use of a blunted bevel tip
1927	GP Pitkin	Needle (20–22 G) with short, blunted bevel with matching stylet	First use of a shorter, blunted bevel tip
1928	LF Sise	Steel needle (20–22 G) with a conical tip	First use of conical tip
1932	M Kirschner	Needle with solid 45° beveled point with a lateral opening	First use of lateral orifice
1944	E Rovenstine	Needle (19–20 G) with closed, short beveled point with lateral orifice 2 mm from the distal end; fitted stylet	First use of lateral orifice with fitted stylet
1950	BA Greene	Needle (20–26 G) with rounded, noncutting, medium length bevel with matching stylet	
1951	S Haraldson	Needle with tapered, noncutting tip with lateral orifice 2 mm from tip	First 'pencil point' closed end, lateral orifice, needle
1951	RJ Whitacre	Needle (20 G) with solid end drawn to a pencil point with lateral orifice	Enabled widespread acceptance of pencil point needle (see below)
1954	Becton, Dickinson & Co.	Whitacre needle	First mass-produced disposable syringe (glass) and needle
1955	Roehr Products		First mass-produced disposable syringe (plastic) and needle
1957	WH Levy	Needle (20 G), sharp pencil point tip with stylet protruding 2–3 mm beyond beveled end; screw mechanism on stylet	First pencil point with end orifice and conical point created by stylet
1987	G Sprotte	Needle with elongated pencil point tip and lateral, large sized orifice	Larger orifice provides faster cerebrospinal fluid and injectate flow
1993	B Braun Medical	Double beveled with sharp point for incision and blunt end for dilation (Atraucan)	First double bevel cutting tip
1996	J Eldor	Pencil point tip with two lateral orifices opposite to each other	First use of two lateral orifices
2000	Rusch France	Pencil point with stylet forming tip (Ballpen)	

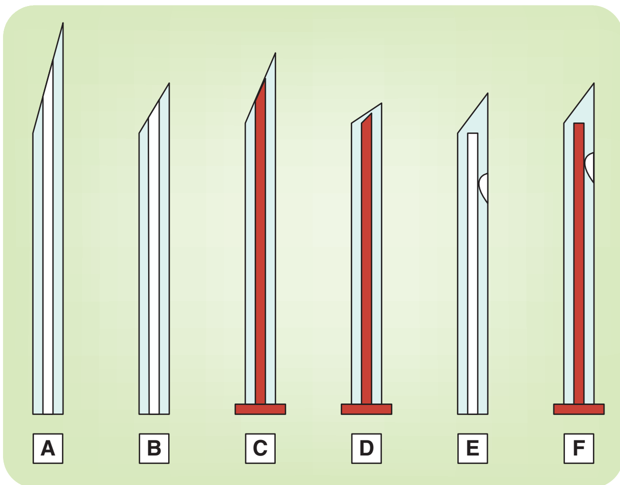

Figure 1. Side profile of cutting spinal needles. (A) Bier (1899). **(B)** Corning (1900). **(C)** Quincke-Babcock (1914), with matching stylet. **(D)** Pitkin (1927), with matching stylet. **(E)** Kirshner (1932), closed tip and lateral orifice. **(F)** Rovenstine (1944), closed tip with matching stylet and lateral orifice. White: open orifice; red: stylet.

The desire for less flexible smaller needles that could be used without an introducer was addressed in a novel way in the 1960s. With advances in manufacturing, both in terms of materials and processes, two needles were designed that employed a taper. A gradual taper and a distal taper were produced, both with the barrel of the needle beginning as a 20 G and tapering to a 24 G at the tip (FIGURE 2). These needles, however, failed to gain widespread acceptance due to their cutting tip and a perceived difficulty with inserting the needle through ligamentous structures.

Needle tip

Early needles were little more than hollow tubes with obliquely sliced tips to allow skin penetration. Corning believed that the bevel tips should be short to limit the penetration of the needle through the dura. Barker further refined and promoted this idea by suggesting that short bevel tips also allowed the whole open end of the needle to be within the dural sac without the point causing injury to the sac contents; moreover, he believed that the short tip prevented the injected analgesics from escaping into the epidural space. Barker initially accomplished this design hypothesis with a traditional Bier needle through which a smaller, blunt tipped, 1 mm longer inner cannula was inserted for injecting medications. In 1907, Barker replaced the inner cannula with a simple, solid stylet with a bevel matching that of the sharp, medium-length needle bevel; removal of the stylet would allow for medications to be injected. Similar sharp needles with medium length bevels and matching stylets were designed in 1914 by Babcock, in 1921 by Labat and as late as 1955 by Brace (FIGURE 1). A novel double bevel cutting tip, with a sharp initial bevel reportedly for the creation of an incision and a second bevel for the dilation of tissues was introduced in 1993 as the Atraucan needle (FIGURE 2).

In the late 1920s, direct examination of dural tissues led to the creation of a smooth rounded, versus a sharp cutting, tip. Greene hypothesized that smoothing the cutting edges of a traditional cutting needle tip would lead to a reduced PDPH rate; indeed his needle, which was produced in 20 and 26 G sizes with a medium length, noncutting bevel and a matching fitted stylet, was associated with a lower incidence of PDPH [1]. Greene further hypothesized that the rounded tip separated, rather than cut, the dural fibers. In 1926, George Praha Pitkin further refined the tip of the blunted bevel by using a shorter, sharper (45°) taper with a matching stylet [1]. He theorized that his needle, which was 20 or 22 G in size, would create a 'trap door' in the dura that would close upon removing the needle; his theory was subsequently disproved by Maxson in 1938 [1]. Haraldson, Hart, Whitacre, and Sprotte offered further modifications to these rounded 'pencil-point' tip needles (see below under orifice location) (FIGURE 3).

A novel modification of the rounded tip needle was the use of a stylet that would serve as the needle tip; when the stylet was removed, a hollow cannula end with no bevel would be within the spinal space. The purported advantages of this design included an orifice that would be completely in the subarachnoid space, which would limit tip protrusion into the spinal sac and allow for rapid, laminar CSF flow. This modification was first theorized by Sise in 1928 [1], but realized by Levy in 1957 with the production of a 20 G pencil-point tip needle with a stylet that protruded 2–3 mm beyond the conical end of the hollow needle [5]. The needle failed to gain

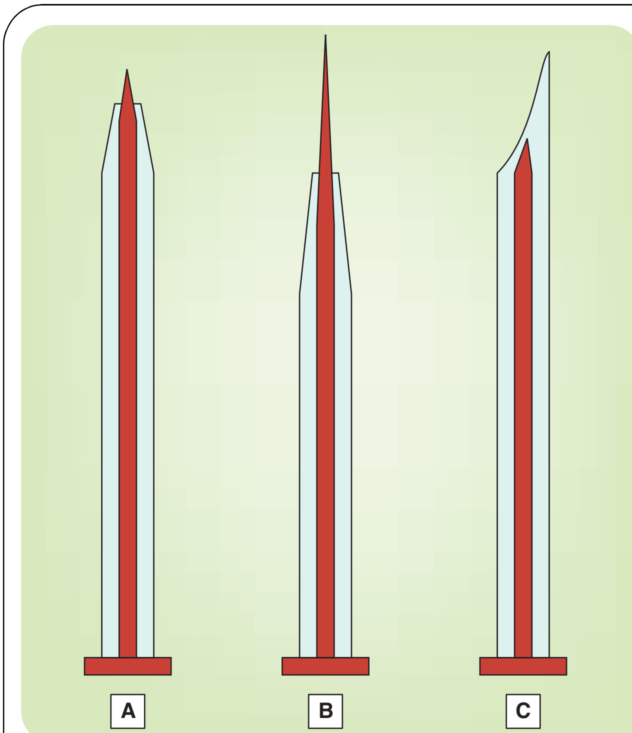

Figure 2. Side profile of cutting spinal needles. (A) Levy (1957), with stylet tip. **(B)** Distal taper (1960s), with matching stylet. **(C)** Atraucan (1993), with double bevel and matching stylet. Red: stylet.

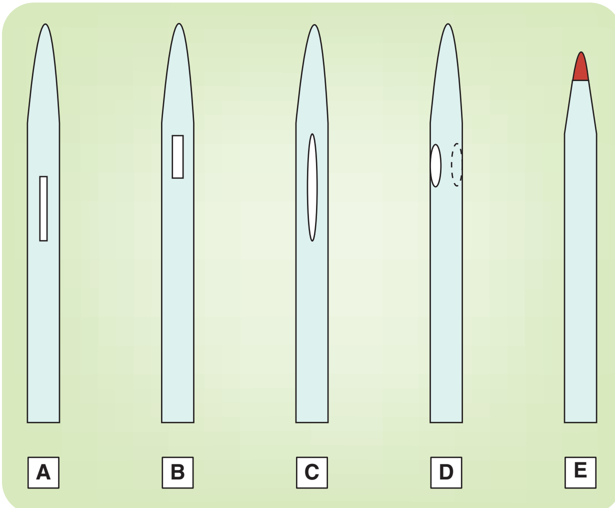

Figure 3. Pencil-point spinal needles. (A) Whitacre (1951). **(B)** Gertie Marx (1985). **(C)** Sprotte (1987). **(D)** Eldor (1996). **(E)** Ballpen (2000), with stylet as needle tip. Note: all pencil-point spinal needles have a stylet (not shown, except in **(E)**, as demarked in red).

widespread acceptance due in part to a screw fixation mechanism for the stylet that was perceived as cumbersome. A similar needle that eliminated the screw stylet mechanism is being currently marketed as the 'ballpen' needle, perhaps due to the design similarity to a retractable ballpoint pen (FIGURE 3) [6].

Orifice location

The earliest needles were essentially hollow tubes with the orifice at the tip of the needle. The introduction of closed-end needles was associated with the development of lateral openings close to the tip. Mentioned first by Barker in 1912, Kirschner from Germany was the first to publish a report using a solid end, 45° beveled spinal needle with a lateral hole in 1932 (FIGURE 1) [1]. Rovenstine further championed the possible advantages of such needles by suggesting that directional anesthesia could be produced. Accordingly, he designed a 19 or 20 G needle with a closed, short bevel and a lateral orifice 20 mm from the tip; a fitted stylet occluded the orifice when seated into the needle (FIGURE 1) [7]. The directionality of the anesthesia produced was not consistently realized [8], and his needle failed to gain popularity, in part due to the deeper insertion into the subarachnoid space required by the orifice location.

The combination of a completely closed, noncutting bevel and a lateral orifice was first introduced by Haraldson in 1951 [9]. He developed a solid, noncutting tapering point needle with an orifice 2 mm from the tip. Hart and Whitacre offered a similar design in a 20 G needle with a solid conical tip and an opening on the side of the needle (FIGURE 3) [10]. Advantages of the 'pencil-point' needle design were reported to include a better feel of the 'dural click' and a lower incidence of PDPH. Sprotte, Schedel and Pajunk created further refinements in 1987 including a larger orifice for greater CSF and injectate flow and a longer, more gradual tip for potentially less dural trauma (FIGURE 2) [11]. The generous size of the orifice prompted questions about the stability of the tip and the possibility of the orifice straddling the epidural and spinal spaces, simultaneously. With further evaluation of needle flow rates, needle orifices have been made smaller [12]; an example of this development can be found in the Gertie Marx needle, which has a smaller orifice located closer to the needle tip than comparably sized Sprotte and Whitacre needles (FIGURE 3). The most recent evolution is a double orifice pencil-point tip created by Eldor in 1996, which has been hypothesized to result in more rapid CSF flow and better distribution of the injectate (FIGURE 3) [13]. Proposed advantages of this needle design include improved CSF flow, better spread of local anesthetic and decreased risk of needle deformation in comparison with single opening pencil-point needles. Puokala and colleagues demonstrated faster CSF flow with a 26 G double hole pencil-point needle (DHPP) when compared with a 27 G Sprotte-type pencil-point needle, however, the flow rate was attributed to the larger needle diameter [14]. Of interest, no differences in the spread of local anesthesia were found, and the DHPP needle appeared more prone to tip damage. By contrast, more rapid CSF flow, higher block level, less vascular trauma and a decreased incidence of PDPH was demonstrated with a 26 G DHPP needle versus a 25 G Quincke spinal needle [15]. The ease of insertion was reported to be easier with the Quincke needle, but the onset and degree of motor blockade was not different.

The distance (~1 mm) between the tip and the orifice location of pencil-point needles versus cutting needles has been hypothesized to result in a higher incidence of paresthesias due to deeper needle insertion and the potential to contact the spinal roots or cord. Below the second lumbar interspace where the spinal cord ends, the 1 mm distance is unlikely to cause a paresthesia from direct spinal cord contact [16]; however, it is not uncommon for needle insertion to occur one or two spaces higher than perceived [17–19]. The incidence of paresthesias between different types of needles has not been fully explored. Whereas a comparison between Sprotte and Whitacre needles demonstrated no difference [20], two studies identified greater paresthesias with the Atraucan versus Whitacre needles (FIGURE 3) [21,22]. Further work is necessary to determine the incidence, as well as the significance, of paresthesias with various spinal needles.

Materials

The introduction of new manufacturing processes and materials has allowed finer needles to be produced. Initially, needles were made with platinum (1853), gold or 'platina' (1885), nickel (1907), iridized platinum or gold (1914), steel (1923) and nickel/silver alloy (1940), and were sterilized and reused. Most spinal needles in current use are made of stainless steel alloys, a combination of iron, carbon and chromium, and since the 1960s were designed to be single use. With improvements in the tensile strength of the materials used, smaller needles have been produced; ultimately, however, the reduction in needle diameter has been limited not by the materials used, but by the displacement and trauma that the needle sustains and the delayed confirmation of intrathecal placement due to the slower flow of CSF.

The introduction of disposable needles was followed by the development of needle hubs made from plastic, rather than metal; the change was implemented as a mechanism to more quickly confirm the presence of CSF flow and to reduce production costs. The use of plastic altered the way hubs were secured to the needle; whereas metal hubs could be molded, welded or interlocked onto the needle shaft, plastic hubs are primarily joined to the needle shaft by adhesives [23]. The resulting adhesive connection has been reported to fail, leading to needle detachment [23] and leakage of the aspirated or injected fluid [24]. Methods to assess the integrity of the needle–hub interface include applying axial traction, checking for malalignment between the hub and shaft, and flushing the needle with the distal end occluded [23,25].

Comparative effects of spinal needle design modifications

Needle diameter

As needle gauges increase, the shaft diameter decreases, leading to a smaller puncture, less CSF leakage and a reduced incidence of PDPH [26,27]. The risk of PDPH with a 27 G Whitacre is approximately 1.7% [26,27]. Although not uniformly demonstrated with pencil-point needles (no difference between 27 and 25 G Whitacre [28] or 25 G and 22 G Sprotte needles [29]), a reduction in PDPH and an increase in patient satisfaction has been observed with the use of smaller diameter cutting tip needles (27 vs 26 G Quincke) [30]. Although these findings would suggest that increasingly smaller needles should be used, the use of such needles may come at the expense of increased technical difficulty in placing the spinal needle as well as higher failure rates of the subsequent blockade.

Needle shaft and tip deviation, bending and trauma is more common with smaller needles, particularly as they emerge from the introducer needle [31]. In comparing Quincke 25 G with Whitacre 25 and 27 G needles, the incidence of shaft bending was similar in all three groups but the deviation was much more pronounced with the 27 G needle [32]. Porcine tissue models corroborate that needle gauge and tip correlate with needle deflection [31], with deflection being more common with cutting tip needles, particularly those with increased tip angles. The angled bevel of cutting tip needles creates tissue resistance and deviates the needle away from the beveled side. The magnitude of the deviation appears most related to the gauge of the needle and is present with smaller needles, even when an introducer needle is used [31,33,34]. Of interest, the introducer itself may have an effect on the deflection of the spinal needle; less deviation is observed when the bevel of the needle is placed 180° to the bevel of the introducer [35].

Technical difficulty and greater failure rates may be related to the amount of time required for CSF confirmation following dural puncture. As the internal lumen diameter of the needle determines the rate of fluid flow, in accordance with the Hagen–Poisselle formula ($Pr\pi^4/8\rho l$), smaller diameter needles have slower flow rates. While decreases in flow as high as fivefold have been demonstrated between 26 and 29 G needles [36], the needle gauge *per se* may not accurately predict flow rates. Needles are produced with different wall thickness; 25 and 27 G B–D spinal needles, for instance, have the same internal diameter due to the 27 G needle having a thinner wall. In addition, flow rate may be a function of the size of the needle orifice; however, if the orifice is larger than the cross-sectional internal lumen of the needle, the lumen is the rate-limiting factor. With 27 G Whitacre and Quincke needles, 10 s elapse between the removal of the needle stylet and CSF visualization [37]. The time delay associated with CSF confirmation may result in multiple dural punctures being inadvertently performed, with each dural puncture increasing the risk of a PDPH and loss of some of the delivered medications from the subarachnoid space. Ultimately, this may result in failure of the motor and sensory blockade produced. In one series with 27 G Quincke and Whitacre needles, an overall 'block failure' rate of 8.5% was observed [37]. Another study with 29 versus 26 G needles found a lower incidence of PDPH with a 29 G needles, however, block failures were more common [38]. These considerations have resulted in many anesthetic practitioners using needles with diameters no smaller than 27 G.

Needle tip

The presence of a cutting versus a rounded tip appears most important among similar sized needles with regards to the incidence of PDPH (TABLE 2). When a 25 G Quincke (cutting) needle was compared with a Whitacre (pencil-point) needle in obstetric patients undergoing cesarean section, a significant increase in PDPH was observed with the Quincke needle, although the headache was usually mild and resolved spontaneously within 48 h [39]. Other investigators have found similar differences with 25 and 27 G needles [26,27,40]. This difference is further emphasized in the greater incidence of PDPH being observed when smaller cutting needles are compared with larger pencil-point needles; 25 and 26 G Quincke needles have been noted to have higher PDPH rates than 24 G Sprotte needles [40,41]. In most circumstances, the incidence of PDPH does not equalize until large size discrepancies in cutting versus pencil-point needles are compared (29 G Quincke vs 22 G Whitacre needles [42] and 27 G Quincke vs 24 G Sprotte needles [43]). The magnitude of this conclusion, which is supported by a meta-analysis [26], is articulated by a study that noted a 50% decrease in the incidence of PDPH when going from a 26- to a 27-G Quincke needle, followed by another 50% reduction when switching to a 25-G Whitacre needle [44]. These findings would support the use of pencil-point versus cutting tip needles.

Among pencil-point needles of similar sizes, the incidence of PDPH and subsequent EBP appear similar; this has not been found to be true with cutting tips, particularly with the Atraucan needle. Vallejo and colleagues performed a randomized comparison of five commonly used spinal needles in the obstetric patient population; of the three pencil-point needles, no difference in PDPH and epidural blood patch was observed [45]. By contrast, although the Quincke and Atraucan needles had

Table 2. Needle type and size and incidence of postdural puncture headache.

Needle description (G)	Postdural puncture headache incidence (%)
Pencil point	
Whitacre 27	1.7
Whitacre 25	2.2–3.1
Whitacre 22	1.5
Sprotte 24	0.7–4.2
Sprotte 22	8
Gertie Marx 24	4
Gertie Marx 22	7
Atraucan 26	2.7–5
Cutting point	
Quincke 27	1.5–3.5
Quincke 26	5.6–9.6
Quincke 25	6.3–8.7
Quincke 24	11.2
Quincke 22	25

similar, but higher, incidences of PDPH, the Atraucan needle was associated with greater EBP use. In part, these relationships may be related to the orientation, shape and size of the dural hole created [46,47]. Anatomic studies have demonstrated that the size of dural punctures is proportional to the size of the spinal needle, and oval versus rounded holes result from cutting and pencil-point needles, respectively [48]. Of interest, and contrary to common wisdom, recent electron microscopy studies of similar sized Quincke and Whitacre needles have demonstrated greater dural fiber disruption with the pencil-point needles [48–50]. By contrast, clean-edged flaps of dural tissue are created with Quincke needles; it is possible that the irregular pencil-point needle dural edges allow for quicker healing, with reduced loss of CSF. It can also be hypothesized that Quincke needles may remove tissue, rather than just displace tissue, at the site of the dural puncture; indeed, tissue particulates are more commonly found within Quincke needles than Whitacre or Sprotte needles, even in small diameter needles (27 G) [51,52]. Contrary to earlier reports [53], bevel orientation (i.e., parallel vs perpendicular to the longitudinal axis of the spinal column) of cutting spinal needles appears to have limited relevance to the amount of CSF leak or the incidence of PDPH [48,54]; this is consistent with recent electron microscopy images demonstrating multidirectional, rather than the previously believed parallel, dural fiber orientation [48]. This being said, the overall relevance of the dural puncture tissue architecture on PDPH, dural healing or CSF flow deserves further investigation.

The incidence of PDPH may also be related to the damage sustained to the tips of modern small diameter spinal needles during the placement [55]. Scanning electron micrographs of Quincke-type needle tips (22–29G) observed that 15% were either bent or hooked following placement. The majority of damaged needles curved inward rather than outward, and the smaller diameter needles were more likely to sustain trauma. Quincke needles appear more prone to damage than Whitacre needles; microscopic evaluation demonstrated burrs or blunting of the spinal tip in 25% of 25-G Quincke needles versus 3 and 10% of 25 and 27-G Whitacre needles, respectively [32]. Most of the needle damage sustained with pencil-point needles was limited to tip blunting, however, the larger, more distant orifice of the Sprotte needle made it more likely to bend at the orifice aperture [56]. Manufacturing defects may be partially responsible for subsequent trauma to the dura. Discrepancies in stylet-to-needle length and needle tip-to-orifice distances, coupled with errors in tip and orifice integrity are not uncommon [32]. These manufacturing issues are more common in the Quincke needles as a number of manufacturers produce the needle and stylet separately.

Orifice location & size

A number of needle design elements affect CSF and injectate flow rates including a needle's diameter, length and orifice location and size with the internal diameter being the most important factor. Needles of the same gauge may have flow rates that vary considerably [36], which has focused attention on needle tip, length and orifice location and size. The 26-G Atraucan needle produces faster identification and greater CSF flow than the 25-G Whitacre needle, which is most likely attributed to the tip design as well as the smaller orifice in the Whitacre needle [21]. By contrast, although faster CSF flow rates are usually achieved by the large orifice of the Sprotte needle, it is possible to straddle the intrathecal and epidural spaces, allowing for slower flow of CSF, injection into the epidural space and a less predictable neuraxial block (FIGURE 3) [57]. Needle length, as noted above, may also have relevance to CSF flow rates; this is particularly true when using the longer spinal needles (up to 6 inches, compared with the standard 3.5 inches) in obese patients or with the combined spinal-epidural (CSE) technique. The CSE technique involves properly identifying the epidural space with an epidural needle and then placing a spinal needle though the epidural needle lumen into the intrathecal sac. Medication is deposited through the spinal needle, the spinal needle is removed, and an epidural catheter is placed. The technique is frequently used for labor analgesia to provide the rapid onset of a spinal technique and the flexibility of an epidural catheter. Although the technique requires only a spinal needle that is several millimeters longer than the epidural needle, special CSE needle kits have been produced that include epidural needles with a separate spinal needle exit hole or lumen, longer spinal needles and devices to secure the position of the spinal needle once CSF has been obtained.

Spinal needle cost

The growing emphasis on cost-effective healthcare has focused attention on frequently used, relatively low cost, disposable equipment, such as spinal needles. The acquisition costs of spinal needles depend on a number of variables (e.g., purchase volume, individual needle or kit purchase and the number of manufacturers and distributors), however, cutting (Quincke) needles are generally less expensive than pencil-point needles. The direct cost advantage of using cutting needles, however, may be offset by the costs associated with a PDPH, including the need for an epidural blood patch, greater staffing requirements and longer hospital stays [45]. Such a cost–benefit has been demonstrated with pencil-point needles in a comparison of Atraucan, Quincke, Gertie Marx, Sprotte and Whitacre needles in the obstetric population, where the incidence of PDPH is high [45]. These costs can be further compounded by malpractice claims associated with headaches, which were the third most common obstetric reason for claims against an anesthesiologist [58,59]. A similar cost analysis of pencil-point needles in the obstetric population suggests an advantage of 25-G Whitacre needles over 24-G Sprotte needles [60]. The likelihood of PDPH modifies the cost analysis for different patient populations; no difference in the incidence of PDPH was found in patients 60 years of age and older undergoing spinal anesthesia with 22- and 25-G Quincke needles or 22-, 25- and 27-G pencil-point needles (no specific needle type identified) [61].

Spinal needles for spinal catheter placement

The benefits of continuous spinal anesthesia via catheters include the ability to titrate the quality and duration of effect and minimize failures rates. Performed with a 20-G macrocatheter placed with a 17-G epidural needle into the spinal space, these efforts were associated with a high incidence of PDPH and a subsequent need for an EBP [62]. As such, the use of smaller (micro) catheters (28–32 G) and needles has been promoted; reports with 32-G catheters placed via 26-G spinal needles, however, were associated with a number of technical complications including an inability to place or inject through the catheter, as well as the risk of catheter shearing, breakage or kinking [63]. The introduction of the 28-G catheter to be used through a 22-G spinal needle led to fewer complications and is a combination in current use outside the USA. Common examples of the needle and catheter sets used in Europe include a 24-G catheter through a 19-G Touhy needle, a 28-G catheter though a 24-G Quincke spinal needle, and a 22-G spinal catheter over a 27-G Quincke spinal needle following an epidurally placed 18-G Crawford needle [64]. Within the USA, reports of cauda equina syndrome (permanent lower extremity weakness with sensory and motor deficits) associated with microcatheters led the FDA to ban their use in 1992 [63]; it is most likely that the manner in which the catheters were dosed (high concentrations and doses of local anesthetics), rather than the microcatheters per se, that contributed to these poor outcomes. Recent studies are again evaluating the potential application of spinal microcatheters within the USA.

Conclusion

From the initial discovery of spinal anesthesia in 1885, the advancement of many applications within the field of anesthesia has been predicated on the continued development of spinal needles. The multitude of needle design elements that can be manipulated, including the needle diameter, tip design, orifice location and size, length and materials, have contributed to alterations in efficacy and side effects of spinal anesthesia; it is these same elements, and perhaps some that are not recognized at this time, that offer an opportunity for the continued advancement and application of the spinal needle.

Key issues

- The combination and subsequent development of the needle and syringe enabled entry into the spinal (subarachnoid or intrathecal) space to collect cerebrospinal fluid (CSF) or inject medications.
- Spinal needles in common use today are 22–27 G with an increase in gauge representing a decrease in diameter.
- Dural punctures with smaller needles allow less CSF leakage and a reduced incidence of postdural puncture headache.
- A small introducer needle with a cutting tip is often used for skin penetration and as a conduit for smaller diameter spinal needles.
- Smaller diameter spinal needles are more prone to shaft and tip deviation, bending and trauma.
- Although early spinal needles consisted of a sharp, beveled hollow needle, the most popular needles for spinal anesthesia are blunt (i.e., 'pencil-point') tipped with a lateral orifice.
- Pencil-point tipped spinal needles are associated with a lower incidence of postdural puncture headache than similarly sized sharp, cutting tipped needles.
- Small microcatheters, which can be placed through the shaft of small diameter spinal needles, are undergoing further evaluation.
- Spinal needles in common use today are disposable and made of a stainless steel alloy.

Expert commentary

Spinal needles have been modified since their first use to produce anesthesia in 1885. Most of the modifications have been, and will continue to be, associated with diameter, tip design, orifice location, and materials used. Pencil-point tipped needles with lateral orifices and small diameters (25–27 G) represent the standard prototype of needle in common use today, due to their reliability and limited association with PDPHs.

Five-year view

Within the next few years, spinal needle design advancements will come not from needle changes *per se*, but through the continued work with microcatheters. These catheters, which can be placed through small diameter spinal needles, will augment analgesic and anesthetic flexibility and maintain a low prevalence of PDPHs.

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