Cardiac Anesthesiology Made Ridiculously Simple

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Cardiac surgery is a dangerous and complex field of medicine with significant morbidity and mortality. Quality anesthetic care with specific attention to detail can greatly enhance patient safety and outcome. Details that are ignored can lead to disaster. This document will attempt to describe the bare bones sequence for cardiac anesthesia for adult CABG and VALVE procedures with specific recommendations. It is not all inclusive or definitive but it is the minimal critical requirements.

If you keep your head screwed on very tightly and pay 100% attention at all times, things will only go poorly some of the time.

A good reference is: "The Practice of Cardiac Anesthesia" by Frederick Hensley and Donald Martin, Little Brown Handbook.

Patient Examination:

Anesthetic evaluation must include attention to cardiac history. The cath report, thallium, echo, and ECG. Critical information includes: Left main disease or equivalent, poor distal targets, ejection fraction, LVEDP, presence of aneurysm, pulmonary hypertension, valvular lesions, congenital lesions. Each of these points requires a modification of anesthetic technique and specific information is required. How is their angina manifest? You need to be able to understand their verbal reports. If a patient's angina is experienced as shortness of breath, or nausea, or heart burn, or whatever, you need to be able to link that symptom to possible myocardial ischemia.

Past medical history including history of COPD, TIA, stroke, cerebral vascular disease, renal disease (CRI is an independent risk factor), hepatic insufficiency will change anesthetic management.

Allergies

Medications : Look specifically for anti-anginal regimen - synergism between calcium channel and beta blockers, is their COPD being treated? It is very important for patients to stay on their anti-anginal therapy throughout the hospital stay. If a patient is on a beta blocker, calcium channel blocker, nitrate, and/or ACE inhibitor they should remain on that drug throughout the perioperative period. The patient should get all anti-anginal medications on the day of surgery and following surgery. The day of surgery is the wrong time to go through a withdrawal process on any anti-anginal drug.

Physical exam: Airway

Chest: Is the patient in failure? Pneumonia? COPD

Cardiac: Do they have a murmur? Are they in failure?

Abd: Ascities, Obesity

LABS: Minimal CBC, Plt, Lytes, BUN, CR, Glu, PT,PTT

CXR: Cardiomegaly? Tumors? Pleural effusions?

ECG: LBBB: Critical information if a pulmonary artery catheter is planned. Occasionally patients with LBBB can develop third degree block with PA catheter placement.

Have they had a recent MI? Do they have resting ischemia? Where are their ST-T changes?

PFT and ABG: Are they going to become a respiratory cripple?

Information: Tell them about the A-line, the PA catheter, and post op ventilation.

Consent: Patients having cardiac surgery have serious and frequent complications including: MI 6%, CVA 5%, Neuropsychiatric Effects 90%, Death 1-3-10% (Depends on risk), Transfusion (40-90%), Pneumonia 10%. You must discuss these risks.

Note: Write a clear note with all the standard details and consent. They will get an Aline, PA catheter, TEE. With the computerized records it is easy to get all the patient's information. Make sure you sign your note so that it is visible to other computer users.

Premedication: These patients are scared. They understand there is real risk. They also will become ischemic with stress. At least 40% get ischemia preop with good premedication. Most will without. Give them oxygen by nasal cannula with some premed: Valium, Morphine, something. Diazepam 10 mg PO on call to OR is a good choice.

Medications Preop: All patients must get their anti-anginals. If the nurses put patient on 9P - 9A BID drugs then state in the chart that patient is to get Drug X, Y, and Z with a sip of water at 6 AM. Otherwise at 9AM they will be in the OR, needing their anti-anginals. Be incredibly clear in your preop orders or they won't get their premeds. Withdrawal of anti-anginal medications during cardiac surgery increases risk of death, MI, CVA, and renal failure. DO NOT DO IT.

PA Catheters: At the present time all bypass cases get the standard monitors plus an a-line, and a pa-catheter. There is an article in JAMA that suggests PA catheters offer little additional information and have inherent risk in ICU patients. As yet, this has not changed our practice. It is clear however that placement of PA catheters must be incredibly skillful without injury to other structures. With no proven benefit all risk must be reduced. One method to achieve this is ultrasonic mapping prior to catheter placement. Remove the towels from behind their head, place the patient in the position you would like, then tape the head in place. Place the patient in tredellenburg. Take a permanent marker and draw out the anatomy, sternocleidomastoid, clavicle, carotid, etc. The more lines the better as it is hard to draw once the ultrasonic goop is in place. Place the blue line in the center of the echo screen. Place the blue dot on the probe to the patient's right. Make sure the probe is absolutely perpendicular to the bed. If you point it at an angle to the bed you will have to take the angle into account and few can do trigonometry in your head. I will be glad to test you on this point. Then take the 5 mHz probe and map out the path of the carotid and the IJ. The IJ is bigger and collapses under pressure, the carotid is round and doesn't collapse under reasonable pressure. If you don't have a line in an appropriate place, wipe off the goop, redraw, and then map again. This technique requires the patient to not move between mapping and placement. I think this system is faster than not using the echo, as you waste 2 minutes mapping, and save 10 minutes of searching with a needle.

Anesthesia: Despite our best efforts we have not been able to demonstrate that one form of anesthesia is obviously better than any other with one exception. Halothane, Enflurane, Isoflurane, high and low dose narcotics, and propofol based anesthetics are equivalent as long as hemodynamics are controlled. Desflurane inductions have been demonstrated to cause pulmonary hypertension and myocardial ischemia. Desflurane is the only anesthetic not recommended for patients with known coronary disease. There is also high dose spinal narcotic (MS 1 mg subarachnoid) but safety data for this technique is limited. During the month you will do two kinds of cases - non research cases during which you should try each of the different techniques to get a feel for them, and research cases with an anesthetic controlled by protocol. With skill, all techniques work, with luck, we may someday know which are truly superior.

Dose Ranges

Fentanyl (High)100-200 mcg/kg (Medium) 20-40 mcg/kg (Low)1-5 mcg/kg

Sufentanyl (High) 20-40 mcg/kg (Medium) 10-20 mcg/kg (Low) 1-2 mcg/kg

Remifentanyl 0.2 to 1.0 mcg/kg/min

Midazolam (High) 3-5 mg/kg (Medium) 2 mg/kg (Low) 0.5 mg/kg

Remifentanyl: To quote one of the great masters of cardiac anesthesia, there are a lot of things that one can do while standing up in a canoe, but why bother? Remifentanyl has a very short half life (5 - 10 minutes) because of its metabolism by non specific cholinesterase. It allows very rapid emergence. It can be used for cardiac anesthesia but the cost is high and some narcotic must be given prior to wake up in the ICU. Reduction in the dose may be possible by giving a longer acting cheap narcotic (fentanyl) to occupy a fraction of the mu receptors and then use the remifentanyl to occupy a smaller fraction. This method of mixing a short half life with a longer half life narcotic may also smooth emergence and prevent accidental emergence should the infusion terminate prematurely. You should try a case with remifentanyl but clearly recognize the dangers and cost of this new drug.

Propofol: You should try a case with propofol used continuously from the start of the case, and one where it is added after bypass. It is expensive but allows a simple technique for early extubation. If early extubation and discharge from the unit is planned the expense of drugs that make it possible is easy to justify.

Dexmedetomidine is an alpha 2 agonist with a 1500:1 alpha 2 to alpha 1 ratio. For example, clonidine has a 30:1 alpha 2 to alpha 1 ratio. It may be used as an adjunct to anesthetics with reductions in MAC or as a post operative sedative by infusion. Its role in cardiac anesthesia is just being figured out.

Planning for Early Extubation: With the health care revolution this is the new thing. The key is multiple little changes in anesthetic technique that make it possible and a good candidate who is problem free to make it work. The problem is simply that many patients appear to be good candidates and then aren't when they get to the ICU, others look like problems and do well. The simplest solution is to treat all patients as candidates for early extubation and then see who qualifies. Early extubation should be planned for in all patients because it requires planning right from the start of the case. The most successful candidates have reasonable cardiac and pulmonary function but it is certainly not a requirement. The changes we have made include limiting fluid given to the patient. Limiting the total narcotic and benzodiazepine dose. Rely on volatile agents or propofol during the case. Provide sedation post op that is easy to get rid of (propofol). Careful control of blood pressure with emergence. Remember some vasodilators (nitroprusside) inhibit hypoxic pulmonary vasocontriction, increase shunt, and make weaning of FIO2 more difficult. Rapid weaning of FIO2 post op is critical. Then extubate the patient. Extubation time is controlled by nursing shift changes and protocols. If you want to extubate early, wean the FIO2 rapidly, wake the patient up, and when the patient meets written extubation criteria do it. It requires a cultural shift to accomplish. The most common reason for delayed extubation is simply V/Q mismatch (shunt) caused by heparin-protamine complexes in the lung. The second most common reason is excessive sedation. Finally, hemodynamics, coagulopathy, etc. get on the list.

Set Up: Standard room set up including Suction, Machine checkout, Airway equipment, Drugs (Succinyl choline, thiopental, non-depolarizing muscle relaxant, atropine, glycopyrolate, ephedrine, neosynephrine (syringe and infusion ready), dopamine (infusion ready), calcium chloride, heparin (30,000 units drawn up), lidocaine and epi in drawer.

Patient Preparation: At least one large IV (< 16g), two are better, a-line on right (left side is occluded by retractor for IMA), take into room and place on O2 for rest of setup, 5 lead for machine, 3 lead for echo, cover V5 with tegaderm. Right IJ PA catheter. Preox while getting baseline values.

Intraoperative Safety: Cardiac surgery has large quantities of blood at arterial and higher pressures. There is frequent splash. You must wear eye protection at all times in the operating room. Expensive goggles around the neck are not acceptable. Put them on at all times in the OR. You should consider the operating room as a woodshop with HIV on all the wood chips. You would not operate power tools in a woodshop without eye protection, do not do it in the OR.

Communication: This operation is a long series of repetitive procedures that absolutely, positively, have to be done correctly. If any are done incorrectly the patient will suffer. Communicate with the surgeon. Ask questions. Tell him what you are doing. If you are having trouble, tell him/her. The operation requires a team approach and you are a member of the team. Don't let your activities or problems be a mystery to the surgeons.

Hypotension: The surgeons can cause profound hypotension with cardiac manipulation. If the pressure suddenly drops or PVC's develop look at what they are doing. Before you give a drug to treat episodic hypotension look to see what they are doing. If you give a drug because of hypotension caused by the surgeons and then they let go of the heart, the pressure will sky rocket. State clearly "Pressure is 70/30) they will get the message and stop lifting up the heart. They may ask you to hand ventilate during some dissection. Watch what they are doing to make sure you are helping not hindering.

Hemodynamics:

Prior to Valve Repairs there are specific recommendations:

AS: Preload: Keep it up **Afterload:** Maintain **SVR:** Maintain **HR:** 50-80 **Rhythm:** NSR

AI: Preload: Keep it up **Afterload:** Down **SVR:** Drop **HR:** 60-80 **Rhythm:** NSR

MS: Preload: Keep it up **Afterload:** Maintain **SVR:** Maintain **HR:** 50-80 **Rhythm:** NSR

MR: Preload: Keep it up **Afterload:** Down **SVR:** Down **HR:** 50-80 **Rhythm:** NSR

Prebypass Hemodynamics: You should try to keep the blood pressure within ± 20% of baseline ward pressure. Heart rates between 40 and 80 are generally fine depending on the clinical situation prior to bypass.

Bypass Hemodynamics: You should keep the MAP between 40-80 during the cold period of bypass (cross clamp on) and between 60-80 during warm bypass (cross clamp off). There will be exceptions such as patients with carotid vascular disease or chronic renal insufficientcy that may need higher pressures (60-80 mmHg) for the entire pump run.

Post Bypass Hemodynamics: Systolic blood pressure greater than 80 mmHg is fine. If it is between 100 and 120 mmHg everyone will be happy. If it is greater than 120 mmHg the patient is hypertensive and there will be more bleeding. Cardiac index greater than 2.0 is fine. Pa Diastolic less than 20 mmHg, CVP less than 15 mmHg. If CVP is ever greater than PAD there is a problem: poor calibration or right ventricular failure. Always consider surgical manipulation of the heart if the chest is open, or tamponade when it is closed, for hypotension.

Preinduction Hemodynamic Measurements: If you put a PA catheter in prior to induction you have indicated that you need it for patient management. You should therefore measure and record SAP, HR, CVP, PAP, PAO, and CO prior to anesthetic induction. If there is a problem you should correct it prior to induction. You can preoxygenate the patient during this time and free up one hand by using the mask strap to hold the mask in place.

Fluids: There are lots of theories on fluids and little data to support the strongly held beliefs. Cardiac cases can easily suck up large amounts of fluid intraoperatively with little obvious benefit. All of that fluid then has to be diuresed postoperatively frequently by administering large amounts of lasix with subsequent electrolyte disturbances. Post operative extubation is frequently delayed by intraoperative fluid administration. Please attempt to limit fluid administration intraoperatively. A few suggestions. If you have two large bore IV's hep lock one of them. Try to give less than 500 cc of LR prior to bypass. Do not administer any fluids during bypass except for fluid required for vasoactive drugs. Use hespan post bypass up to 20 cc/kg, then shift to albumin. If you use hextend, the 20 cc/kg limit may or may not apply. Use a mechanical metering device on any carrier lines to prevent accidental high flows. Use neosynephrine to support pressure before giving large amounts of fluid prebypass.

Fluid Tally's: Tally the estimated blood lost, and fluids administered including crystalloid, colloid, Blood, cell saver, pump blood, bypass prime volume, and total fluid given by perfusionist on your record. This is a change from previous efforts where we ignored everything but the crystalloid, colloid, given by anesthesia, and the blood given by anesthesia and perfusionists. The perfusionists can give large amounts of crystalloid and we need to note it on the anesthesia record. if they give hespan or hextend in the pump prime we should know about it.

Ischemia: Patients have CABG surgery because of myocardial ischemia. 40% of patients undergoing CABG surgery have intraoperative episodes of myocardial ischemia. You should record a 5 lead ECG prior to induction for a baseline comparison. Ask the patient if they are having chest pain at this time. You should look at the ECG either continuously or at least every 60 seconds and ask - What is the rhythm? Is there ischemia? Only by absolute attention to the ECG will you detect a substantial fraction of the ischemia.

When the blood flow to myocardium is insufficient, it immediately stops contracting. This process takes 5 to 10 seconds. At 60 to 90 seconds the ECG ST-T wave starts to change. This focal reduction in cardiac function can be detected by watching the ECHO image. The best level is a short axis mid papillary view. You should record a fixed pre incision short axis mid papillary view for comparison. The ECHO is an adjunct to care not a requirement. Do not ignore the patient when looking at the echo.

Induction and Intubation: Never induce the patient without a surgeon who can put the patient on bypass in the room. Never induce without a perfusionist and a pump. They should be able to place the patient on bypass in less than 5 minutes if the patient arrests on induction. They can't do that, if they aren't there and you will be liable. Take care to avoid hypotension and hypoxia (really? Yes!). Try to limit the LR for the case to less than a liter. That means less than 500 cc prior to bypass. Use 500 cc bags to avoid run away infusions. Most people you put to sleep drop their blood pressure. In cardiac cases we attempt to limit the drop by giving vasoactive substances. There are two approaches to giving these drugs. You can induce the patient and then respond to the hypotension in the 95% of patients that you induce. The alternative is to start a neo infusion in all patients prior to induction and then turn it off when not needed. The second approach is vastly smoother and easier on everyone because you don’t have to scramble around getting something going.

TEE: We are not supposed to use Cidex any more to clean the probes. Therefore you will be issued something that looks like Dr. Ruth Westheimer was consulting at Marine World. Please try to maintain professional demeanor when performing this procedure. Roll the latex prophylatic over the plactic filler device. Then fill the reservoir tip with ultrasonic jelly. There are two

types of plastic fillers: large and small. If you have a small one, remove it as the probe can't fit through it. If you have a large one, the probe can fit through it. Then place the probe in the sheath and roll it all the way down. Get your mind out of the sewer! Next, empty the stomach of air with an NG tube, make sure the probe is unlocked, use a laryngoscope to place it in the esophagus, and treat it like it cost $50,000, as it did. Always use a bite block if the patient has teeth. TEE can be detrimental to patient care if one ignores the patient while using it. It is an adjunct to patient care not a substitute or a requirement. It is useful for detecting air, ASD, VSD, AS, AR, MR, MS, volume status, aortic plaque, myocardial ischemia, regional and global ventricular function, valvular function, anatomy, etc. It will take some time to get good at it but is well worth the effort. The TEE exam frequently causes a modification in the surgical plan. Unrecognized aortic plaque shifts to patient to off pump CABG, or alters the cannulation site, or cancels the case. The sooner it is done, the sooner the surgeons can decide on what to do next.

Always unlock it before removal. Hold onto the ET tube when removing the probe as one can extubate the patient accidentally. Discard the latex condom and then clean the probe.

Baseline ACT and ABG: Obtain after induction

ACT: There are three techniques. Hemochron and HemoTech.

The Hemochron system has two techniques Celite and Kaelin. Celite is diatomaceous earth (dirt) in a tube. You need 2 cc in the tube. Push the button to start the clock. Shake 6 times (with cap on). Place in machine. Rotate the tube to get the green light to turn on. Fully heparinized ready to go on bypass is greater than 450 seconds. If used with Aprotinin, it needs to be above 800 seconds. Kaelin is a white liquid in a dual tube cassette with little plastic flags. Fully heparinized, ready to go on bypass is greater than 450 seconds.. It is unaffected by Aprotinin.

The Hemotechn system has little plastic cartridges with two little plastic flags. It looks like a two hole miniature golf set. The cartridge should be warmed in the machine prior to use. Carefully, using a blunt needle, place blood up to the little black line in each of the two wells. Do not get drops of blood between the flag and the tube, as it will not work. Place the cartridge in the machine and click the mechanism onto the cartridge. Same times apply for on pump.

Sternotomy: Painful process that occurs rapidly after induction, make sure the patient is adequately anesthetized. They will ask you to let the lungs down during opening. You must disconnect the patient from the ventilator and reconnect after they open the sternum. Develop a system to prevent yourself from forgetting to place patient back on ventilator. Do not rely on the alarm as the only reminder.

Redo Heart Sternotomy: In a redo heart the adhesions may bring the ventricle close to the sternum. The sternal saw may cut through the right ventricle with resulting (profound) hemorrhage. You should have blood available and 2 large IV's. You may also cut through the IMA or a saphenous graft. You should have an idea of what this will do from the catherization report and a plan. Instant severe myocardial ischemia with rapid deterioration may result. The case is easier if the IMA and grafts are not functional. Functional grafts that the patient is dependent on is the most dangerous situation.

IMA Dissection: They may want the table tilted to the left and elevated. They may want the tidal volumes reduced and the rate increased to help with dissection. It may be very hard to get an echo image during IMA dissection

Heparinization: Do not allow the surgeons to go on bypass without heparinization. If the patient is not heparinized when the clamp is opened on the bypass pump, the pump and oxygenator will clot and the patient will most likely die. If the surgeons are placing a cannula in some artery ask if they want the heparin given. When they ask for heparin, respond with a verbal statement - the heparin has been given. Always use the central line for heparin. Aspirate blood from the line before and after the heparin dose to check to make sure the line is in a vein. The dose of heparin is 300 U/kg which is about 21 cc of 1000 u/cc heparin in a 70 kg man. Check the ACT a minute or two after the dose. Do not use the same IV to draw the blood that you infused the heparin in. (i.e. draw an arterial blood sample). You want to check the ACT quickly because it needs to be above 450 seconds to go on bypass and that is 7.5 minutes of waiting if you forget and have not drawn the blood sample. If the patient is on heparin preop, give the same dose (Heparin 300 U/kg). Do not stop the preop heparin just be careful putting in lines. Do not give anti-fibrinolytics until fully heparinized (amikar). If the ACT is not greater than 450 seconds after the dose, give more, until the ACT is above 450 seconds. If you are using aprotinin the celite ACT must be above 800 seconds. If a kaolin ACT is used the normal 450 second range is used.

Add heparin to your ACLS protocol for cardiac surgery patients. If the patient arrests give the heparin so that patient can be put on bypass for resuscitation.

All patients getting cardiac surgery using extracorporeal circulatory support should get an anti-fibrinolytic drug. There are several choices. It may be that all should get aprotinin, unless given in previous surgeries, but this change has not been universally adopted. At the present time we use a two tier approach.

All patients going on extracorporeal circulatory support should have an anti-fibrinolytic. If they are a first time case without risk factors they get amikar. If they are a redo case, a case with renal failure, a case with a high risk of bleeding, or a Jehovah's Witness where bleeding would be lethal, they get aprotinin.

Amikar: Epsilon amino caproic acid used as a antifibrinolytic. Some evidence that it reduces post bypass bleeding. Some clinical reports of problems (left ventricular thrombus, arterial thrombi, etc.) Commonly given as 5 g IV prior to bypass and 5 g IV after bypass. Can be given in higher doses 10 g prior and 10 g after in large patients. Much less expensive ($12/bottle) than aprotinin ($900/bottle) although the efficacy is not proven. No FDA indication for this use. No convincing safety data. We are using it on all cases. Give 5 g IV slowly after you give the Heparin prior to bypass. Give 5 G IV slowly after the protamine is in. You do not want to give it prior to heparin. There are adverse events associated with protamine administration and it is easier if only one drug can be blamed for each event.

Aprotinin: Antifibrinolytic and platelet preserver that reduces bleeding and transfusion associated with CABG surgery in redos and people on aspirin. Costs $900/case. The transfusions for a case average $1000 so the cost is revenue neutral. If one considers the risk of disease transmission from transfusions amprotinin is a benefit. There is an increased risk of graft closure from clotting. If one looks at the morbidity and mortality associated with take backs for bleeding, aprotinin reduces risk of death. It is allergenic so patients should probably only have one use in a lifetime. That use should probably be for a redo CABG.

Our present use is for REDO CABG, patients with renal failure, patients with risk of bleeding, or patients in which bleeding would be lethal (Jehovah's Witness). Order 6 M units (3 200cc bottles at 10,000 units per cc). Give 1 cc test dose, then 20 cc over 20 minutes starting prior to skin incision. Then continue at 0.5 M U/hr. The perfusionist will prime with 2 M units so give one bottle to them. I have tried to avoid using a fourth bottle in long cases by slowing the infusion to 0.3 to 0.4 M U/hr so that the infusion bottle will last until the end of bypass. Lower doses of aprotinin work, so this slower infusion is probably reasonable. Remember celite ACT 800 seconds, kaolin ACT 450 with Aprotinin.

What operation are we doing today?: Cardiac surgery used to be done using extracorporeal support. A few surgeons did CABG without the pump but it was rare and usually done elsewhere. In the last few years the percentage of CABG surgeries done using off pump techniques has risen dramatically. The invention of the octopus and starfish have made it easier, safer, and practical for most CABG operations to be done off pump. At the present time we are randomizing patients to "on pump" versus "off pump" care. If the decision seems random, you are correct, it is. The anesthetic care is fundamentally different for these two approaches so we will separately discuss the "ON PUMP" anesthetic care and then the "OFF PUMP" approach. You need to be flexible because they can change their mind at a moments notice.

Placing the cannulas:

Either check a twitch or give more non depolarizing neuromuscular blocker prior to cannula placement. If the patient takes a breath with the atrium open, they can have gas embolization and have severe injury.

Do not allow the surgeons to go on bypass without heparinization. The arterial pressure at this point should be below 120 mmHg. The small cannula in the aorta (has a red tape on it) should not have any bubbles in it. If you see a bubble tell the surgeons immediately. When they put in the aortic cannula there is splash - have your glasses on.

The larger cannula with blue tape is the venous cannula and goes into the apex of the right atrium into the inferior vena cava. It is a drain line and may have bubbles. On mitral valve and ASD/VSD cases there will be two smaller drain lines into the superior and inferior vena cava.

The small cannula with a balloon at one end is placed into the coronary sinus through a purse string in the right atrium. If this is used they will ask you to measure the pressure in the cannula. Hook this to the CVP transducer. When the flow in the coronary sinus cardioplegia line is 200 ml/min the pressure should be about 40 mmHg. If the pressure is like CVP and does not go up with coronary sinus flow (retrograde cardioplegia), the cannula is not in the coronary sinus. If this happens during continuous warm cardioplegia, there is a period of warm ischemia which can result in severe ventricular dysfunction and death. If the pressure is very high (greater than 100 mmHg) with a flow of 200 ml/min the cannula is against the wall and you also may not be having good retrograde cardioplegia.

The left ventricular vent line is placed through the right superior pulmonary vein. It decompresses the left ventricle.

Check List for Going on Bypass:

HAD2SUE Remember this mnemonic. Say it often. Avoid killing patient by using it.

Heparin: Always give prior to bypass.

ACT: Always check before going on bypass (450 seconds)

Drugs: Do you need anything (Non depolarizing neuromuscular blocker).

Drips: Turn off the inotropes etc.

Swan: Pull the PA catheter back 5 cm to avoid pulmonary arterial occlusion/rupture.

Urine: Account for bypass urine

Emboli: Check the Arterial cannula for bubbles.

Clean Kills and the Perfusionist: There are three easy ways for the perfusionist to kill the patient.

1. No oxygen in the oxygenator.

2. No heparin.

3. Reservoir runs empty.

If the power goes out there is a crank for the perfusionist - you may be asked to help crank.

If a line breaks, you may have to help replace it.

Air Lock: The venous line drains by siphon. Nothing is quite as reliable as gravity but air introduced into the venous system can cause the loss of the siphon. If the perfusionist notes bubbles on the venous return line, or you do, check the integrity of the cordis, closure of all stop cocks, the surgeons will check the atrial purse string. If you reduce pump flow temporarily the venous pressure will rise and the air leak will diminish. The lines can be refilled with saline if complete airlock occurs.

Cardioplegia: There are lots of types. Cold, Warm, Warm induction - Cold Maintenance - Warm Repercussion, Hot Shot, Crystalloid, Blood, Antegrade, Retrograde. The best is a short cross clamp with a skillful surgeon. You should record the on bypass time, the off bypass time, the on cross clamp, the off cross clamp. As the cross clamp time exceeds 1 hour ventricular function deteriorates, as it exceeds 2 hours it gets worse. Cardioplegia during cross clamp helps. There are lots of things added to cardioplegia and the bypass prime and you should find out what they are from the perfusionist. They will say something like "Nothing special" which translates into potassium, lidocaine, aspartate, glutamate, D50, manitol, bicarb, adenosine, free radical scavenger of the day, and snake oil. Ask and you will learn. There is much magic in the cardioplegia bag, most of it only in the eye of the orderer. If something weird happens on bypass (ie pressure goes to 30, potassium sky rockets, glucose is very high) consider what is in the cardioplegia solution.

De-Airing Maneuvers: It is bad to pump air to the patient. It is difficult to get all of the air out and doppler studies of the middle cerebral artery during bypass demonstrate 50-2000 emboli per case. It is hard to decide if this is air or atherosclerotic plaque. The smaller the bubble the bigger the echo signal. On open ventricle or aortic procedures the surgeons will have you place the head down. Then they will bump the patient, roll from side to side, stick a needle in the ventricle, aspirate from the aorta, etc. in the hopes of getting out all of the bubbles. They will direct you on what they want. If you look at the echo at this time there will be a snow storm of little bubbles in the ventricle. If you see a large one or more than usual say something.

The majority of emboli occur on aortic cannulation, cross clamp placement, cross clamp removal, side bitter placement, side bitter removal, weaning from bypass, and aortic cannula removal. It is best not to have high glucose or overly warm temperatures (37^{o}C) during any of the embolic times. 95% of patients suffer subtle neuro-psychiatric changes consistent with multiple small emboli.

Check List for Getting Off Bypass:

WRMVP: Wide receiver most valuable player.

Warm: What is the bladder and blood temp?

Rhythm: Are they in NSR or do you need to pace? Is the rate adequate?

Monitors On: Turn em back on if you turned them off for bypass. Turn back on the alarms.

Ventilation: Turn on the ventilator. Easy to forget and you look very stupid.

Perfusion: What is the pump flow.

Weaning from bypass: You need to have a plan. What was the ventricular function prior to bypass? How long was the cross clamp? What does the heart look like now? What is the resistance now? Once you have a plan communicate with the surgeon. If you plan to use a drug with prolonged side effects ask them what they think (amrinone, milrinone). They may have an opinion that should be considered. Have some inotrope ready. You should be able to wean 80-90% of first time CABG patient's from bypass with no inotropes. Calcium chloride is commonly used. Excessive doses (2g) have been associated with pancreatitis.

A standard weaning plan would be to calculate the systemic vascular resistance (SVR):

SVR = [(MAP - CVP)/CO]*80

MAP: Mean Arterial Pressure

CVP: Central Venous Pressure

CO: Cardiac Output (Can be obtained by asking the perfusionist what the pump flow is)

SVR should be in the 1000 to 1200 wood units. It routinely will be 600 to 800 and the cardiac output necessary to develop a reasonable pressure post bypass will be too high. Vasoconstrictors (phenylephrine) or a catecholamine with some vasocontrictive effects (dopamine, epinephrine, norepinephrine) are commonly necessary to raise the resistance to reasonable levels. Here is an example. The MAP is 50 and the CVP is 10. You ask the perfusionist and he tells you the pump flow is 5 liters/min. That gives a SVR of (50-10)/5*80 which equals 640 wood units.

Let's take two approaches. The first is to come off pump and let the heart try to pump sufficiently to develop a reasonable pressure. Once off pump the SVR will be 640, the MAP will be 50 and the BP will be about 70/40. The problem is not cardiac in nature. The problem is simply low resistance. An inotrope is not needed a vasocontrictor is.

If the SVR had been raised to 1200 prior to coming off pump, the 5 liter/min cardiac output would yield a MAP of 65 with a CVP of 10. The BP would then be about 95/50 and all would be well.

A reasonable approach to weaning from bypass is to:

a. Make an educated guess as to the inotropic state of the ventricle. If it was lousy prior to bypass, it will most likely still be lousy and an inotrope will be necessary. If the inotropic state of the ventricle was ok prior to bypass and cross clamp times were reasonable (60 minutes or less) then it is likely no inotropes will be needed.

b. Calculate the resistance and correct it.

c. Check the requirements for coming off pump. Warm, Rhythm, Monitors On, Ventilator On, Perfusion (resistance reasonable).

d. Be ready to change your plan.

Why does the patient "go on bypass"? and How does the patient "come off bypass"?: The bypass system is basically a large plastic pipe with lots of holes placed through the right atrial appendage into the inferior vena cava. The large plastic pipe is full of fluid and hooked to the venous reservoir. The pipe is clamped with a large clamp. Note: Before attempting any of this activity, (not recommended in the privacy of your own home) make sure you have fulfilled the criteria for going on bypass (HADDSUE) or coming off bypass (WRMVP) as noted above. **NEVER LET THEM GO ON PUMP IF YOU HAVE NOT HEPARINIZED.** Having an ACT greater than 450 is very reassuring but not absolutely essential in dire and I mean dire emergencies. Other than the dire emergency. ACT must be greater than 450.

The simple explanation for going on bypass is the perfusionist removes the clamp from the venous drain line and a siphon effect drains blood from the right atrium and inferior vena cava into the venous reservoir. It is important to maintain the siphon effect to keep this flow going. Since, there is no or less blood going into the right ventricle, the cardiac output drops. The perfusionist then turns on the pump and returns the blood to through the aortic cannula into the patient's aorta. If all is working well the blood will be heated/cooled and oxygenated by the heater/cooler/oxygenator before being pumped through the filter and back into the aorta. Unclamping the venous drain line reduces the right atrial pressure and diverts blood into the pump. The perfusionist will say something like "Full flow" which means they have 4 or 5 liters a minute of venous drainage and are able to pump 4 to 5 liters/min into the patient. At this point you can turn off the ventilator. Pulmonary artery pressures should be non-pulsatile.

Coming off pump is the exact reverse situation. You fulfill all the criteria for coming off pump. (WRMVP), i.e. the patient is warm, the heart is beating, the monitors are turned on, the ventilator is turned on, and you have adjusted the resistance and inotropic state to an appropriate level. The perfusionist then partially occludes the venous drain line. This reduces the amount of blood draining into the venous reservoir. The right atrial pressure increases and blood starts to go into the right ventricle and out the pulmonary artery. At this point you can have a pump flow that is a fraction of the total systemic blood flow with the rest produced by the heart. The surgeon will say something like, Leave some in and come to 4 liter/min. You will notice that the pulmonary artery and systemic pressures become pulsatile. They will then drop to say 2 liter/min then 1 liter/min. They are watching the right and left ventricles to make sure they are not distending. They also watch the pressures and slowly load the heart. When they say something like "Give a hundred". What they are telling the perfusionist is to leave 100 cc less blood in the reservoir. The perfusionist may be draining 2 liters/min of blood from the patient and pumping 2 liter/min to the patient. They are supposed to pump 100 more cc of blood than they withdrew. It is an inexact science. But you get the idea.

The surgeon will then clamp the venous drain line and you can tell that you are truly off pump. They will remove the venous cannula. If you have a kind surgeon, they will place it in a bucket of saline and then drain the blood back to the reservoir keeping the line full of saline. This allows the perfusionist to start hemo concentrating the blood in the system but keeps the venous line ready in case you have to return to bypass. The arterial line is still in place so the perfusionist can give fluid. When the patient's blood volume is low you will hear - "give a hundred". The perfusionist basically unclamps the arterial line with the pump on and drains 100 cc of fluid from the reservoir.

Who weans the patient from bypass and who gives volume orders? This varies by institution and surgeon. At some institutions the anesthesiologist does at others the surgeon does. If you are not ready to wean a patient, say so. If you think the patient needs to go back on bypass, tell the surgeon to put the cannulas back in. If the patient is doing poorly, tell them not to take out the arterial cannula. If you need more volume, ask for it. You are part of the team. This is one surgery where it is essential that you be able to tell the surgeon what to do, and when to do it. When things are going bad, communication is key. It is essential that it is a team process. They need to know what you need and what is going on. If something is not working, they need to know about it. They can and will most likely try to fix it.

Inotropes and Vasoactive Compounds: If you are using a drug that requires an infusion and where the effects of an incorrect or fluctuating dose would be difficult to manage, use an infusion pump. This includes (dopamine, dobutamine, epinephrine, norepinephrine, nitroprusside, nitroglycerin, neosynephrine, and propofol). The fluctuations caused by relying on gravity drips are unacceptable. Gravity is reliable, back pressure is not. All drugs must be mixed in concentrations approved by the pharmacy. The labels with the appropriate concentration are in a black box in the anesthesia machine. If you mix it and label it with the yellow label then the ICU nurses will not throw it away when you get to the ICU. If you mix some weird concentration, label it poorly, or then put it on a dial-a-flow, the nurses will throw away your drugs and the patient will get less than optimal care.

Prophylactic Drugs: Some surgeons believe that prophylactic high dose steroids are thought to reduce the immune reaction to bypass or reduce neural injury. Scientific evidence for these theories is limited. Downside to steroids are infections and poor wound healing. Some surgeons believe in prophylactic inotropes or vasodilators. Post bypass prophylatic nitroglycerin infusions

have been suggested as a preventative measure for IMA spasm and myocardial ischemia, downside is hypotension, supply limited ischemia, and more fluid requirements to keep preload adequate. Magnesium is thought to be an anti-arrythmic, anti ischemic agent. Some people load with magnesium prior to CABG surgery (2 grams IV) others do not. The scientific evidence for many of these therapies is equivocal. Once again you have to communicate and ask your surgeon their preference. You will have to come to some sort of intelligent, professional compromise on prophylactic drug use.

Phosphodiesterase Inhibitors: Do not start a phosphodiesterase inhibitor (Amrinone, Milrinone) without talking to the cardiac surgeons. Do not choose it as first line inotrope. A phosphodiesterase inhibitor will vasodilate profoundly and will most likely require a second drug with vasoconstrictor properties.

Potassium: Low potassium is defined as less than 4.0 meq. It is associate with arrhythmia's. Replace if less than 4.0. High potassium depends on timing. Greater than 5.0 is common on bypass from the cardioplegia. You would like it to be below 5.0 but greater than 4.0 when you come off pump. The perfusionist can dialyze the patient if needed.

Hematocrit: Drops with the hemodilution of the bypass pump. If it is below 20 you need to correct. Between 20-25 you need to use clinical judgment. Talk to the surgeons, they may have an absolute rule and if you don't follow it, they will simply follow it in the unit and be irritated with you in the OR.

Post Bypass Hemodynamics: Systolic blood pressure greater than 80 mmHg is fine. If it is between 100 and 120 mmHg everyone will be happy. If it is greater than 120 mmHg the patient is hypertensive and there will be more bleeding. Cardiac index greater than 2.0 is fine. Pa Diastolic less than 20 mmHg, CVP less than 15 mmHg. If CVP is ever greater than PAD there is a problem: poor calibration or right ventricular failure. Always consider surgical manipulation of the heart if the chest is open or tamponade when it is closed, as a cause of hypotension.

Protamine: Fish semen in a bottle. There are allergic, anaphylactic, and histamine responses. Dose is personal but Protamine 10 mg will equalize Heparin 1000 units. Protamine comes as 10 mg per cc so if you used 30 cc of heparin, 30 cc of protamine will neutralize it. You are forming a weak salt between a base and an acid. You are titrating the response. You need to give the dose and then check the response by measuring the ACT. Some of the V/Q mismatch and shunt post op is caused by clearance of heparin-protamine complexes by the reticulo-endothelial system in the lung.

Protamine Administration: Give 10 mg = 1 cc peripherally and check for allergic response manifested as hypotension, broncospasm, rash, or pulmonary hypertension. Stop administration for problems. You can get severe hypotension from protamine, be ready with phenylephrine. Steroids, H1& H2 blockers, vasoconstrictors, inotropes, and returning to bypass can help. Allowing the heparin to spontaneously be metabolized is another option for severe reactions.

Then give the rest of the dose slowly. What is slowly? If you follow the PDR it would be about 2 hours. If you are at some institutions it would be 1 minute. Over 20 minutes is not unreasonable. Once 1/3 of the protamine is in tell the perfusionist so that they can stop the pump suckers and avoid clotting the pump. If you clot the pump and need to return to bypass you will be very, very, very unhappy.

Once all the protamine is in, tell the surgeons, and then check an ACT. You should return to baseline (120 - 130). If you have not, give more protamine. If you give pump blood after this point you may need to give more protamine. You can only find this out by measuring the ACT. Check the ACT after you give blood products from the pump or cell saver.

Post Bypass Bleeding: If there is bleeding post bypass, check the ACT. If elevated, correct it. If there was aspirin given in the last 4 days you may need platelets. If there is medical bleeding, you may need platelets. If there is surgical bleeding, they should fix it with a stitch or the bovie not infusions of platelets. Recently a new factor was discovered in the clotting cascade it is a 6-0 proline.

Returning to Bypass: If there is severe hypotension, bleeding, low cardiac output, other problems, you may need to return to bypass. If you have given the protamine, give another dose of heparin at 300 U/kg and check an ACT. Before the aortic cannula is removed, you should make a decision about whether you may need to return to bypass. If you are having severe problems maintaining the pressure despite inotropes, tell the surgeons. They will delay removing the aortic cannula or immediately return to bypass. It is very bad for the heart to be dilated by high filling pressure and then have low coronary perfusion pressure. You may have to return to bypass.

Balloon Pump: Very nice system for inadequate left ventricular function. The balloon pump needs an ECG signal and an arterial pressure signal. On the Datex monitor the slave cable plugs into channel 3. Channel 3 is usually the CVP channel. Plug the CVP

cable into channel 4 and change the label on channel 4 to CVP. To switch to slave mode the easiest thing to do it get a new pressure transducer. Hook the new arterial transducer to the balloon pump and plug the cable into channel 3. Change the label on channel three to ABP. This will make the trace red and the scale 0-200. Then plug the slave cable into channel three and send it to the balloon pump. There is a switch on the balloon pump that tells it to lok at external ECG and arterial pressure from the slave cable. Both settings must be switched. Do not hesitate to suggest if there is difficulty weaning from bypass.

LV Assist Device: Transportable centrifugal pump that can be used as a bridge to transplant or to allow recovery of severely stunned myocardium.

Closing the chest: May cause hypotension if inadequate volume status. Check a cardiac output after closure. If the lungs seem too large or the heart is lifting out of the chest, consider broncospasm with air trapping. Bronchodilators, ventilator and ETT adjustment can help.

Removing the TEE: Unlock it before removal! Call somebody to clean it.

Transport: Have the patient monitored at all times. Never remove the ECG until another is working. Place the transport leads, get it to work, then remove the OR leads. Do not change the A-line if hemodynamically unstable. Quickly re-zero. If you elevate the transducer 13.6 cm you will reduce the arterial pressure 10 mmHg. Keep the transducers at the right level. Be paranoid. If there is a problem. Stop and fix it.

Sudden hypotension on moving the patient: It is very common for the blood pressure to sag when the patient is moved from the operating table to the bed. This phenomena is not well understood but may be from reperfusion dependent tissues with the shift to the bed. The patient can have profound hypotension. Most patients drop their filling pressures noticibly. Have volume available. Do not make the shift if the patient is unstable or volume deplete. Fix the problem prior to the shift. Have volume, some drug to raise the pressure, some drug to lower the pressure, oxygen, mask, and any other drugs you have been using with you on transport.

ICU: Shift the monitors in the same way. The cartridge for the transport monitor simply plugs into the ICU monitor. If you don't have this system get the ICU ECG working before removing the transport ECG/ Do not shift the A-line until the patient is hemodynamically stable. Listen to the chest immediately after hooking to the ventilator. If there is sudden hypotension suspect a problem the ventilator (infinite peep) and remove the patient from the ventilator and hand ventilate. Then get a new ventilator. Do not allow the nurses to change to their inotropes until you leave. Do not allow them to remove your iv's until you leave. Do not leave until the patient is truly stable.

When to Extubate: The checklist for extubation should include: No evidence of myocardial ischemia, infarction or failure, Hemodynamic stability on limited inotropic support, (no balloon pump or multiple inotropes with sweat dripping from the cardiac fellow's brow), limited bleeding without a coagulopathy (chest tube drainage below 50 cc/hr for 2 hours), good gas on FIO_2 is 0.40, SIMV 8, PEEP 5, TV = 10 cc/kg, the patient is awake and breathing, good gas on CPAP 5 cm H_2O FIO_2 =0.50 then extubate. Talk to the surgeons about your plans, they may have a very good reason why this patient is a lousy candidate (The grafts were poor, there is bleeding, there is tamponade.)

Anesthesia for Minimally Invasive Cardiac Surgery: MID-CABG or Off Pump CABG

I guess the first question should be what to call this new operation. It is minimally invasive CABG or minimal access CABG. Maximally difficult CABG. I don't know. A little cabbage is commonly known as a brussel sprout. This operation is changing rapidly. These is now a history to how it was done. That implies that we have maybe improved it.

Initially, there was the Heart Port operation. The marketing plan of the Heart Port System was to avoid that nasty sternotomy scar. Most people coming for a CABG are past the age when the scar will prevent them from being in the case of Bay Watch. The operation was simple, no that's not right. An arterial inflow cannula was placed in a femoral artery and the venous outflow was placed through a femoral vein. A catheter with a balloon was advanced up the aorta and the balloon inflated in the ascending aortic arch. Aortic atherosclerotic disease was a definite contraindication for this operation. Picture sliding the catheter up a severely diseased aorta followed by retrograde perfusion from the groin. Cardioplegia was then delivered antegrade to the coronary arteries which have been separated from the systemic circulation by the ascending aortic arch balloon. A catheter was advanced from the internal jugular vein into the pulmonary artery for venting the left ventricle. The patient was placed on fem-fem bypass and cardioplegia established. A single vessel CABG was then performed either through a mini thoracotomy or thoracoscopically. The problem with this operation is obvious. The risk from with a CABG is the extracorporeal circulation not the sternotomy. One of the major morbidities of CABG surgery is the neuropsychiatric changes and strokes. The Heart Port

operation has a long bypass run for a single vessel CABG. It maximizes the risk of stroke while eliminating the sternotomy. This operation was doomed to failure from the start.

CTS (Chuck Taylor Surgical or Cardio Thoracic Surgical) and US Surgical worked to improve the technique popularized by Bennetti. It was in essence a mini-thoracotomy with no bypass. The standard was a single IMA to the LAD. The heart was stabilized by placing latex sutures under the LAD proximal and distal to the site of the anastamosis. A small foot presses on the myocardium while the sutures pull the heart into the foot. Blood flow was stopped in the target vessel by the stabilizing sutures. The technique requires improved technical skill on the part of the surgeon because the heart is moving (contraction as well as respiratory movement). It also requires increased technical skill on the part of the anesthesiologist because an area of myocardium is ischemic, and non -functional, and prone to reperfusion arrythmias. The advantage of the operation is reduced cost (no extracorporeal circulation, reduced hospitalization time) and reduced risk of stroke (no extracorporeal circulation). If surgeons and anesthesiologists can surmount the technical challenges (motion, bleeding, arrythmias, hemodynamics, exposure) it offered great promise. On the down side, the operation was difficult and inferior wall vessels were hard to appoach.

Octopus and Starfish. These retractors use suction to stabilize the heart. Instead of squashing the heart with a foot like the CTS system, the Octopus system sucks up the myocardium with two little arms. The arms then separate slightly to tighten the area and reduce motion. The Starfish is retractor for lifting and moving the heart with a suction cup shaped like a Y. With these retractors hemodynamics are much improved during stabilization.

The equipment for MID-CABG is changing constantly. The fundamental problems have not. One of the first problems to address is what is the plan when the patient has ventricular fibrillation. If the surgical plan consists of a small thoracotomy what is going to happen when the ischemia caused by the stabilizing sutures or the reperfusion arrhythmias caused by releasing the sutures progresses to ventricular fibrillation? The second problem is maintaining venous return despite the efforts of the surgeon.

My favorite plan is this.

1. Choose an anesthetic that lowers the heart rate (fentanyl, sufentanyl, alfentanyl, remifentanyl).

2. Use a median sternotomy approach. The morbidity is small compared to the risk of prolonged ventricular fibrillation. Have the perfusionist available. Don't prime the pump but have it completely set up and ready to prime. Don't hand off the lines just be ready. If you can't convince the surgeon to do the case as a sternotomy from the start be ready for the emergency sternotomy when the patient fibrillates. The other advantage of the sternotomy from the start approach is multivessel CABG without extracorporeal circulation is possible. With the mini-thoracotomy multiple mini-thoracotomies are needed for the second and third distal anastamosis. If you end up doing a MID CABG with multiple mini-thoracotomies, consider using a double lumen tube for better exposure. They are not essential but frequently help.

3. Anti-coagulate the patient just as you would for a CABG with extracorporeal circulation (Heparin 300 U/kg). If there is a problem it is easy to cannulate and go on pump.

4. Prophylax for arrhythmias with you favorite drugs. Magnesium 2 gram IV plus Lidocaine 100 mg followed by an infusion at 2 mg/min. I am a strong proponent of amiodarone (IV). If you have arrythmias start amiodarone 150 MG over 10 minutes, then 1 mg/min IV for 6 hours, then 0.5 mg/min for 18 hours.

5. After the surgeon has retracted the heart, placed the stay sutures and the stabilizer, load the patient with volume (hespan / hextend) and maintain the pressure with vasoconstrictors. I try to avoid beta agonists because of the tachycardia and pro-arrythmic effects. Tachycardia makes the anastamosis more difficult. You will spend a lot of time adjusting hemodynamics only to have all your work reversed when the heart is let out of whatever position it is in. Steep trendellenburg is very useful for inferior wall distal anastamosis.

6. Adjust the ventilator to reduce motion (small tidal volumes with increased rate).

7. Have a plan to lower the heart rate even more if necessary (esmolol, adenosine). If the heart rate is irregular or too low use atrial pacing. Do not use glycopyrolate or atropine when asked to increase the heart rate because they are hard to undo when the surgeon changes his mind.

8. Be ready for reperfusion arrythmias with release of the stay sutures.

9. Reverse the heparin gently. Remember you don't have a bypass circuit ready to bail you out. Moreover, the dose of protamine may be reduced because of the lack of damage to the platelets. Check the ACT 1/3 and 2/3 of the way through the protamine to avoid overdosing.

10. Consider anticoagulation post reversal of protamine. CABG surgery benefits from prolonged damage to the coagulation system. When was the last time you saw a post CABG pulmonary embolus? When do they start anticoagulating after a valve? In a Off Pump-CABG where the coagulation system was not exposed to an extracorporeal circulation circuit the coagulation system is normal. All of the problems with pulmonary embolus, graft closure, graft clotting that the vascular surgeons have will now occur with cardiac surgery. If graft closure causes a cold leg and a mid-night trip to the OR to remove the clot for vascular surgeons. Off Pump CABG graft closure causes an MI and possibly a cold blue patient and a trip to the morgue. Be very, very, very careful about post operative MI's. Remember the anastamosis was done in less than optimal circumstances (movement, bleeding, limited positioning). The coagulation system is fully functional. We are trying dextran infusions to try to have some prolonged anti-coagulant effect without bleeding. The jury is still out though.

We have had thirty years to figure out all the tricks for normal CABG's. The Off Pump-CABG is still in its childhood.

Good Luck: You should enjoy your month at the VA. You will get a reasonable experience with adult cardiac surgery. If there are any comments, changes, additions, errors in this text, I, Art Wallace, M.D, Ph.D., am responsible. Please e-mail me with suggestions.

by Art Wallace, M.D., Ph.D.

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