

## Cardiac Anesthesia Made Ridiculously Simple

Cardiac surgery is a complex field of medicine with significant morbidity and mortality. It is however performed routinely with systems designed to facilitate an ordered throughput of patients. Currently around 80% of cardiac cases at RPAH and Liverpool Hospitals are day-of-surgery admissions. However, operating lists may be changed at short (or no!) notice to accommodate emergency cases. Patients may even be cancelled after induction of anaesthesia. Quality anesthetic care with specific attention to detail can greatly enhance patient safety and outcome. Conversely, details that are ignored can lead to poor outcomes. This document will attempt to describe the essential requirements for cardiac anesthesia for adult CAG and VALVE procedures. The intention is not to be definitive but to outline the minimal critical requirements.

### Pre-operative Consultation

Most commonly this is performed in the cardiac pre-admission clinic for elective cases. A full pre-anaesthetic history and examination should be performed with particular reference to the following points which may affect anaesthetic management or indicate the patient's risk:

#### History:

Present illness: angina (stable or unstable), dyspnoea (systolic or diastolic dysfunction), recent myocardial infarction (has it occurred since the decision to operate), episodes of cardiac failure, flash pulmonary oedema. Time in hospital or transfer from another center? MRSA risk?

Co-existing disease: CAL/asthma, diabetes, hypertension, cerebrovascular disease- has this patient had fits, faints, funny turns or visual disturbances, peripheral vascular disease (claudication), renal insufficiency. Coexisting AAA?, Haemostatic disorder.

Hypercoagulability disorder. Dental check performed for valve replacements?

Social/cultural Will they understand the co-operation required for line placement?

Central / PAC best inserted pre -or post induction.

Allergies especially to Heparin, Protamine (seafood), Iodine, antibiotics

Medications: anti-hypertensives, anti-anginals, anti-arrhythmics

Specific regimes for diabetes and asthma, heparin infusions (what have serial platelet counts been ([HITTS](#)?) Heparin infusions are usually continued up until patient arrival in theatre.

Have they stopped their aspirin and NSAIDS ? OPCAB patients may sometimes remain on aspirin.

Beware of newer [antiplatelet agents](#)- enoxaparin (Clexane), should be ceased about 24h preop. Clopidogrel (Iscover, Plavix) should be stopped 5-7 days preop. Abciximab (Reopro) -avoid CPB for 5-7 days. Tirofiban- avoid CPB for 24-48h.

Antifibrinolytics: streptokinase- avoid CPB for 2-3h.

History of Reflux/Dysphagia: Rapid sequence induction in these patients may pose particular challenges. The placement of TOE probes maybe hazardous in patients with oesophageal disease ( strictures ).

### Physical Examination

Do they look unwell? Are they SOB at rest? Do they look grey and shut down? Have the signs of left ventricular dysfunction been masked by diuretic use?

Airway, Dentition - anticipated difficult intubation?

Chest: CCF? Murmurs? CAL?

Head & Neck: movement, carotid bruits? JVP, previous carotid surgery scars, beards - will trimming be required for line placement? (usually not).

Periphery: pulses, nb: is radial artery being considered from the non-dominant hand?

Venous access?

Investigations:

CXR - cardiomegaly, effusions, aortic calcification, lungs lesions?

ECG - rate, rhythm, conduction abnormalities, pacemaker dependent, ischaemia, recent infarction, territory of infarcts.

FBC - Hb, platelets

Coags. Prolonged APTT in the absence of heparin (Lupus antibody)

Xmatch Does blood bank have suitable blood for an antibody-positive patient?

Electrolytes - K<sup>+</sup>, creatinine

BSL, HB A1c

Recent peaks of CK, CKMB, Troponin

Coags, ABG's, LFT's

Carotid Duplex Dopplers especially if patient has had symptomatic cerebral symptoms

Cardiac Catheter & [Echo Report](#) - note the following:

Coronary vasculature - number, site and severity of stenoses esp. LMCA disease or equivalent

LV Function - LV Ejection Fraction, LVEDP, pulmonary artery pressures

Valvular lesions - areas and gradients:

Information:

Tell patients about fasting, medications, line placement, and post-op ventilation and analgesia.

Patients having cardiac surgery have serious and frequent complications including infarct, stroke, death. Risk of stroke increases rapidly with age over 65, hypertension, diabetes, previous stroke.

Mortality 1-10% (depends on risk stratification - see below), transfusion (< 40%) inevitable in patients less than 50 kg, Chest infections. You should discuss these risks. Diabetics should be warned that their insulin requirements may change markedly, and that non-insulin dependent diabetics may become insulin-dependent, at least transiently. Patients with renal failure should be warned of the increased likelihood of temporary dialysis post-op.

Risk Stratification:

The following factors greatly increase risk associated with cardiac surgery:

Age >80, uncompensated cardiac failure, cardiogenic shock, acute renal failure

The following factors moderately increase risk:

Age >70, re-operation, emergency surgery, pulmonary hypertension, chronic renal failure

Other factors resulting in increased risk:

Diabetes, hypertension, obesity, Ejection fraction <40%, valve surgery, LV aneurysm, female gender

Premedication:

These patients may be very concerned. They are serious risks involved. They may develop myocardial ischaemia with stress. Many CAG patients will get ischaemia preoperatively even with good premedication.

Lorazepam 2mg or temazepam nocte prn night before

Lorazepam 2mg 0600 morning of surgery

Morphine(5-10mg) at 0630 for a 0800 start, on call for later cases.

Oxygen need to be charted with the premed as hypoxamia is likely to occur otherwise.

Supplement with midazolam as soon as the peripheral line is in. Don't let these patients suffer anxiety (and ischaemia) during line insertion.

Fast all (adult) patients from midnight as the order of the list may change unpredictably.

### Medications Preop:

All patients should get their usual antianginals, antiarrhythmics and antihypertensives. State in the chart that patient is to get Drug X, Y, and Z with a sip of water at 6 AM. Aspirin, clexane, NSAIDs and oral hypoglycaemics should be stopped. Heparin can be continued to the anaesthetic bay.

Diabetics on insulin should be first on list if practicable. One scheme is to give no insulin preop and start insulin infusion after induction with regular BSL determinations. Otherwise give half usual dose and start glucose infusion at 0700.

### PA Catheters:

At the present time, nearly all bypass cases get the standard monitors plus an arterial line and a PA catheter via the RIJ vein.

### Anaesthesia

No form of anaesthesia has been demonstrated to be better than any other with two exceptions. Desflurane and Ketamine inductions have been demonstrated to cause pulmonary hypertension and myocardial ischaemia. These are the only anaesthetics not recommended for patients with known coronary disease. Thiopentone is used in hypnotic doses only at induction (50-125mg.) Isoflurane, Sevoflurane, high and low dose narcotic-based anaesthesia are equivalent provided haemodynamics are well controlled. Heart rate control is particularly important as intraoperative tachycardia is associated with myocardial ischaemia and infarction in CABG patients. Nitrous oxide is avoided because of potential problems with expansion of gaseous emboli in open heart procedures.

### Specific Drugs:

Fentanyl: Dose ranges (High) >100 mcg/kg (Medium) 20-60 mcg/kg (Low) 5-10 mcg/kg. We tend to use low-medium fentanyl doses for most cases (usually 1mg in total for off-pump cases and 2mg for on-pump cases). Isoflurane, Sevoflurane, propofol and benzodiazepines can all be used in various combinations to supplement the opiate.

Remifentanyl 0.2 to 1.0 mcg/kg/min can also be used but to quote one of the great masters of cardiac anaesthesia, 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 esterase. It allows very rapid emergence. It can be used for cardiac anaesthesia 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: Propofol can be used continuously from the start of the case, and one where it is added after bypass. It is relatively 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 to justify. Can be given by standard infusion or TCI using the Diprifusor.

### Planning for Early Extubation: ("Fast-Tracking")

Early extubation (within 6 hours postoperatively) may lead to reduced ICU duration and lower costs without increasing patient morbidity. Generally only low-risk cases are suitable candidates for early extubation. On-table extubation may be possible in OPCAB patients or following short bypass runs (eg for ASD repair) but it has not been demonstrated to be of clinical benefit.

Early extubation should be discussed at the beginning because it requires planning right from the start of the case. Attention should be paid to limiting intravenous fluids, limiting the total narcotic and benzodiazepine dose and most importantly, keeping the patient warm. Put the Bair-Hugger on in the anaesthetic room and keep it on over as much of the

patient as the surgery will allow. Do not consider extubating the patient if their temperature is less than 35.5° at the end of the case. Postoperative with a propofol infusion is also useful. Careful control of blood pressure with emergence may be necessary.

Set Up:

Standard room set up including suction, machine check, airway equipment, Drugs: narcotic +/- thiopentone, pancuronium, metaraminol / phenylephrine, antibiotics, GTN and morphine infusions. The default catecholamine support is either adrenaline or noradrenaline. The heparin is drawn up by the perfusionist (400u/kg) Protamine should not be drawn up until patient is off bypass to minimize the risk of potentially fatal syringe-swap.

Patient Preparation:

ECG hookup in anaesthetic room, O2 via mask. Two iv's ( 14g or 16g), 20 g radial arterial line - on left unless surgeons intend to harvest the left radial, CVP / PAC in RIJ. External defib pads for re-dos and very high risk cases ( > 70 % L main, ischaemic emergencies from the cath lab) Note the passage of a PA catheter in recent infarcts involving the right ventricle can lead to VF.

Intraoperative Safety:

Cardiac surgery can be bloody. There is frequent splash. You should wear eye protection at all times in the operating room. Gloves should be worn esp. during line insertion, TOE handling and intubation.

Communication:

Cardiac anaesthesia involves a series of repetitive procedures that absolutely, positively, have to be done correctly. Communicate with the other anaesthetists and the surgical team. Ask questions. Tell him what you are doing. If you are having trouble, tell someone. 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. Cardiac surgeons thrive on stress. Sometimes this manifests as being openly critical when you show your inexperience / ignorance by asking questions. Don't let this upset you. Better to ask and risk criticism than harm the patient.

Preinduction haemodynamic Measurements:

In very high -risk cases consideration should be given to inserting a PA catheter in prior to induction. You should therefore measure and record SAP, HR, CVP, PAP+/- CO as it may be necessary to initiate inotropes prior to induction.

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 frusemide with subsequent electrolyte disturbances. Post-operative extubation is frequently delayed by overzealous intraoperative fluid administration. Please attempt to limit fluid administration intraoperatively. The exception are patients undergoing pre-CPB plateletpheresis, fluid loading with at least 2 litres of crystalloid will be necessary. A few suggestions: pre-induction, patient may require fluid loading if the cardiologists have dried them out. Try not to exceed 2 litres pre-bypass, usually one is adequate. Use metaraminol to support pressure before giving large amounts of fluid prebypass. Post bypass patients will vasodilate and vasodilatation is also common after off- pump CABG as well. Noradrenaline is often required.

Ischaemia:

Patients have CABG surgery because of myocardial ischaemia. 40% of patients undergoing CABG surgery have intraoperative episodes of myocardial ischaemia. Monitoring leads II and V5 will pick up the majority of ischaemic episodes detectable by ECG.

When the blood flow to myocardium is insufficient a wall motion abnormality develops within 5 to 10 seconds. At 60 to 90 seconds the ECG ST-T wave starts to change. TOE

monitoring will detect ischaemia earlier than the ECG and abnormal wall motion due to ischaemia may occur without ECG changes. The best view for monitoring for ischaemia is the short-axis mid-papillary view.

Induction and Intubation:

Never induce the patient without a surgeon who can put the patient on bypass in the vicinity. Never induce without a perfusionist and a pump available in case the patient arrests on induction.

Patients are almost always induced on the operating table, fully monitored (with audible "beep") and pre-oxygenated. For a standard (non-fast tracked) case, induction will consist of fentanyl 500 to 1000mcg, +/- thiopentone 50-200mg or midazolam and 8-12mg pancuronium. The slight tachycardia from the pancuronium antagonises the bradycardia from the fentanyl. Following intubation the TOE probe is inserted (unless there is a contraindication).

TOE Probe.

Cost \$65,000 easily damaged - treat with extreme respect. Always use a bite block and plenty of lubricant. TOE can be detrimental to patient care if one ignores the patient while using it. It is an adjunct to patient care and not a substitute. It is useful for detecting air, ASD, VSD, AS, AR, MR, MS, volume status, aortic plaque, myocardial ischaemia, 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.

ACT:

Cellite tubes are used. Put 2ml blood in the tube, put into the Hemachron machine and press the button to start the clock. The ACT should be greater than 400 seconds prior to initiating CPB. If Aprotinin has been used, it needs to be above 750 seconds or 400 seconds if the yellow-top (kaolin) tubes are used.

Sternotomy:

A long period where there is little stimulation occurs following induction. Once surgery starts, there is a relatively short period before the painful stimuli of sternotomy and (even more stimulating) sternal retraction occurs. Hence it is important to ensure that the patient is adequately anaesthetized prior to incision. You must disconnect the patient from the ventilator during sternotomy to avoid tearing the pericardium. Develop a system to prevent yourself from forgetting to recommence ventilation (eg hold the tube in your hand while the patient is apnoeic). During redo sternotomy with an oscillating saw it may not be necessary to cease ventilation.

Re-do 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 or innominate vein with hemorrhage. You should have blood available and a large bore IV. You may also cut through the IMA or a saphenous graft. You should have an idea of what this will do from the catheterization report and a plan. Instant severe myocardial ischaemia with rapid deterioration may result. The case is easier if the IMA and grafts are not functional. A functional grafts that the patient is dependent on is potentially the most hazardous situation.

IMA Dissection:

The surgeons 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. They may also request hand ventilation. This means keeping an eye on the lungs and making sure they don't get in the way of the surgeon. If they ask for "lungs off" to assist with a difficult dissection make sure you remember to turn the ventilator on again! (easily forgotten!).

Haemodynamics:

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 hypotension firstly establish that it was not produced by temporary surgical manipulation. State clearly "Pressure is 60/30") 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.

Prebypass haemodynamics:

In general you should try to keep the blood pressure around 90-120mmHg (systolic) and the heart rate between 50 and 80 depending on the clinical situation prior to bypass. During purse string insertion, BP should be brought down to around 100 to prevent aortic dissection during cannulation. Papaverine injection by the surgeon during mammary artery harvest may drop the pressure transiently to 70 or so. Don't be too eager to give aramine, lest the pressure hit 160mmHg just as the surgeons want to cannulate. Tachycardia and hypertension should first be treated by further anaesthesia and fentanyl. Esmolol or metoprolol are useful drugs if tachycardia and hypertension coexist. Clonidine 75-150 micrograms is useful but if pressure is already very high there is a transient rise in BP unless it is given as 20mcg doses. Phentolamine 1-2 mg is good for short-lived alpha blockade.

For patients with valvular disease there are specific recommendations:

In general, preload should be maintained in the normal range. Afterload reduction is good for MR and AR whilst afterload maintenance is good for stenotic lesions. Heart rate should be controlled to 60-80 for stenotic valves, 80-100 for incompetent ones. Tachycardia with severe mitral stenosis can be life-threatening.

Bypass Haemodynamics:

MAP is generally kept between 40-50mmHg during the cold period of bypass (cross clamp on) and between 50-60mmHg during warm bypass (cross clamp off). There will be exceptions- such as patients with carotid vascular disease or chronic renal insufficiency that may need higher pressures (60-80 mmHg) for the entire pump run. The perfusionists control the pressure on bypass but may ask you to give more narcotic or vasodilator.

Post Bypass Haemodynamics:

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 should be less than 20 mmHg, and the CVP less than 15 mmHg. (assuming they were previously in the normal range) If CVP is ever greater than PAD there is a problem: poor calibration or right ventricular failure. If hypotension occurs, always consider surgical manipulation of the heart if the chest is open, or tamponade when it is closed. Difficult haemodynamic problems can be sorted out with TOE.

Heparinization:

Do not allow the surgeons to go on bypass without heparinization!

If you learn nothing else, learn this. Heparin is THE most important drug in cardiac anaesthesia.

The only "syringe-swap" guaranteed to kill the patient is giving something else instead of heparin. If the patient is not heparinized when the clamp is opened on the bypass machine, the pump and oxygenator will clot. 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 is in."

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. If you can't aspirate blood choose a different lumen. If you choose the lumen that SNP or Tridil has been going through, avoid giving a bolus of vasodilator! If there is another line piggy-backed to the one you are using for heparin, make sure the heparin doesn't run up the side line!

If an IMA is being harvested, the surgeon will ask for the heparin prior to detaching the distal end, otherwise they will ask during purse string insertion into the aorta or right

atrium. Heparin can (and should be) given as a bolus over 10-15 seconds. There is often a slight drop in systemic pressure due to ionized hypocalcaemia. (cf. protamine : MUST be given by infusion over 10-20 MINUTES otherwise severe hypotension may result)

The dose of heparin is 400 U/kg. Check the ACT at least one minute after the dose. You can use an arterial or venous blood sample as long as you aspirate an adequate volume of dead space. You want to check the ACT within a few minutes because it needs to be above 400 seconds to go on bypass, which 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 400 U/kg). If the ACT is less than 400 seconds after the dose, tell the surgeon and perfusionist, and give more Heparin until the ACT is above 400 seconds.

Amicar: Epsilon aminocaproic acid has been used as an antifibrinolytic. Reduces post bypass bleeding but is not as effective as aprotinin. Some clinical reports of problems (left ventricular thrombus, arterial thrombi, etc.) Commonly given as 10g IV pre bypass. Much less expensive (\$12/bottle) than aprotinin (\$80/bottle).

Aprotinin: Antifibrinolytic protease inhibitor that reduces bleeding and transfusion associated with CABG surgery in redos and people on aspirin. Costs \$200/case. If one considers the risk of disease transmission from transfusions aprotinin is a benefit. Some surgeons do not like their patients receiving this drug because of concerns that it may be prothrombotic. However, this phenomenon has been shown to be due to under-heparinisation, aprotinin prolongs the cellite ACT (black top) we use at RPAH. Hence the ACT on bypass must be kept over 750 seconds who have received aprotinin. Aprotinin is occasionally allergenic so beware of patients having had it before, especially within 3 months.

Placing the cannulas:

During cannulation the BP should be kept as close to 100 systolic as possible in order to minimise the risk of aortic dissection. If the pressure is greater than this, the surgeon will wait impatiently (foot-tapping, sarcasm, etc.) for you to get it down. In CABG cases, a 3-5 ml bolus of GTN (300-500mcg) may be helpful in producing rapid, transient hypotension. Do not allow the surgeons to go on bypass without heparinization.

In fact, they shouldn't even cannulate without heparin. If you see them about to cannulate and the heparin is not in, yell STOP! And tell them why. The small bore cannula in the aorta should not have any bubbles in it. If you see a bubble tell the surgeons immediately.

The larger cannula with blue tape is the venous cannula and goes through the apex of the right atrium and 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 for retrograde cardioplegia administration. A pressure manometer line will be passed over for connection with a male to male connector at the PA transducer. This will measure coronary sinus pressure during retrograde cardioplegia administration.

Check List for Going on Bypass:

HAD2SAVE Useful mnemonic pre -CPB

Heparin: Always give prior to bypass.

ACT: Always check before going on bypass (400 seconds)

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

Drips: Turn off the inotropes etc.

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

Alarms: Disable alarm tones (ECG, BP, CO2 etc)

Ventilator: turned off once patient is safely on bypass ("full flow")

Emboli: Check the Arterial cannula for bubbles.

**NEVER LET THEM GO ON PUMP IF YOU HAVE NOT HEPARINIZED!**

On initiating bypass, 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 via the arterial cannula into the patient's aorta. The blood will be heated/cooled and oxygenated by the heater/cooler/oxygenator. The perfusionist will say something like "Full flow" which means that the pump flow has reached around 2.2L/min/m<sup>2</sup>. At this point you can turn off the ventilator. Pulmonary artery pressures should be low. After bypass is established the gas analysis line may be transferred from the ETT connector to the membrane. This needs to be returned prior to re-establishing ventilation. Leave a bung on the patient connector when you disconnect the gas line.

There are three serious perfusion errors.

No oxygen in the oxygenator.

No heparin.

Reservoir runs empty with [massive gas embolism](#).

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 Reperfusion, Hot Shot, Crystalloid, Blood, Antegrade, Retrograde. There are a variety of different formulae but the only essential ingredient is potassium- to induce diastolic arrest.

All open procedures should be done with carbon dioxide insufflation into the pericardium at two litres per minute. This is because retained intracardiac CO<sub>2</sub> is less harmful than retained air (as it is much more soluble). The majority of emboli occur on aortic cannulation, cross clamp placement, cross clamp removal, side biter placement, side biter removal, weaning from bypass, and aortic cannula removal. It is best not to have high glucose or overly warm temperatures ( 37 C) during any of the embolic times. 30% of patients suffer subtle neuro-psychiatric changes consistent with multiple small emboli. **De-Airing manoeuvres:** On open ventricle or aortic procedures the surgeons will have you place the patient head- down. You may also be asked to deliver a valsalva breath (to de-air the pulmonary circulation). If you look at the echo at this time there will be a snow storm of little bubbles in the ventricle.

Check List for Weaning from Bypass:

**Warm:** What is the nasopharyngeal temperature (must be at least 36.5°)?

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

**Monitors (Alarms) On:** Turn em back on if you turned them off for bypass.

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

**Perfusion:** What is the pump flow? Vasoconstrictors may be necessary if the MAP is < 50mmHg on "full 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? Once you have a plan communicate with the surgeon. If you plan to use a drug with prolonged side

effects (amrinone, milrinone) you should discuss this with the surgeon. 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

One 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 unit range. It is often 600 -800 and the cardiac output necessary to develop a reasonable pressure post bypass may well be too high.

Vasoconstrictors (metaraminol) or a catecholamine with some vasoconstrictive effects (dopamine, adrenaline, noradrenaline) are commonly necessary to raise the resistance to reasonable levels. Here is an example: The MAP is 50 and the CVP is 10. The perfusionist tells you that the pump flow is 5 liters/min. That gives a SVR of  $(50-10)/5*80 = 640$  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- hence a vasoconstrictor rather than an inotrope is needed.

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:

Make an educated guess as to the inotropic state of the ventricle. (and look at the ventricle on TOE) 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 O.K. prior to bypass and cross clamp times were reasonable (60 minutes or less) then it is likely no inotropes will be needed.

Calculate the resistance and correct it.

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

Be ready to change your plan.

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. The pump flow is gradually reduced as blood is transfused to the patient and progressively more work is being done by the patient's heart. You will notice that the pulmonary artery and systemic pressures become pulsatile. Careful attention is paid both the right and left ventricles to make sure they are not distending. When the perfusionist says "Off on venous" the venous line has been clamped and the patient is being slowly transfused. "Give a hundred" means the perfusionist is being asked to transfuse 100 ml of blood from the reservoir.

Once both venous and arterial lines have been closed the patient is off bypass. Once the patient is stable, the surgeon will remove the venous cannula. The arterial line is still in place so the perfusionist can give continue to transfuse blood if necessary.

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. It should be a team effort. If the patient is doing poorly, tell surgeon not to take out the arterial cannula. If you need more volume, ask for it. You are part of the team,

it is essential that you communicate effectively with the surgeon, especially when things are going badly.

**Inotropes and Vasoactive Compounds:** If you are using a drug that requires an infusion (such as [adrenaline](#) or [noradrenaline](#)), it must be via an infusion pump or syringe pump with a standard concentration that is acceptable to CICU and properly labeled. If you mix some weird concentration, label it poorly, or put it on a dial-a-flow, the nurses will throw away your drugs and the patient will get less than optimal care.

**Phosphodiesterase Inhibitors:** Do not start a phosphodiesterase inhibitor ([Milrinone](#)) without talking to the cardiac surgeons. Do not choose it as first line inotrope.

Phosphodiesterase inhibitor may produce profound vasodilation and will most likely require a second drug with vasoconstrictor properties.

**Potassium:** Low potassium is defined as less than 4.0 meq. It is associated with arrhythmias. 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.

**Haematocrit:** Drops with the haemodilution of the bypass pump. Can drop very low in small patients with low Hb to start with (low red cell mass). If it is below 20 it may need to be corrected. Between 20-25 you need to use clinical judgment.

**Post Bypass Haemodynamics:** Systolic blood pressure greater than 90 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:** The standard dose used is [Protamine](#) 1 mg for Heparin 100 units. Protamine comes as 10 mg per ml, and Heparin 1000 units per ml. So, if you used 30 ml of heparin, 30 ml of protamine will theoretically neutralize it. The post-reversal should be less than 120% of normal (<150seconds). Give initially slowly and check for allergic response manifested as hypotension, bronchospasm, rash, or pulmonary hypertension. Stop administration for problems. You can get severe hypotension from protamine, be ready with metaraminol. Steroids, H1 & H2 blockers, vasoconstrictors, inotropes, and occasionally, it may even be necessary to return to bypass. **NEVER GIVE PROTAMINE WHILE YOU ARE STILL ON BYPASS!** Sounds obvious but it is surprisingly easy to do and may kill the patient. 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 consider doing another ACT. It should return to baseline (120 - 130). If it hasn't, give more protamine. If you give pump blood after this point you may need to give more protamine due to the heparin in the pump-blood.

**Post Bypass Bleeding:** If there is bleeding post bypass, check the ACT. If elevated, correct it. Most non-surgical bleeding is due to platelet dysfunction, hence platelet transfusion may be necessary.

**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 400 U/kg and check an ACT. If you there is a possibility you gave an excess of protamine, you need to neutralize the circulating free protamine as well - give another 10,000 units heparin to be safe. When returning to bypass it is better to be over heparinized than under!

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 may

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.

Intraaortic Balloon Pump: May improve ventricular function in a failing heart by improving coronary perfusion pressure. Placement may be aided with the use of TOE. The pump is synchronized with the ECG or the arterial pressure trace. LV Assist Device ([Abiomed](#)) or [ECMO](#) are also available if things are going really badly.

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

Removing the TEE: Unlock it before removal!

Transport: Have the patient monitored at all times. Don't leave the theatre without adequate haemodynamics. The bed transfer often leads to hypotension.

Anesthesia for Minimally Invasive Cardiac Surgery: MID-CAB

"MIDCAB" This is in essence a mini-thoracotomy with no bypass. The procedure requires a double-lumen tube and one lung ventilation. The standard is a single IMA to the LAD. The heart is stabilized by placing latex sutures under the LAD proximal and distal to the site of the anastomosis. A small foot presses on the myocardium while the sutures pull the heart into the foot. Blood flow is stopped in the target vessel by the stabilizing sutures. External defibrillator pads must be attached to the patient as the heart cannot easily be defibrillated internally via this incision. On-table extubation is usually possible, so a warming blanket must be applied as soon as possible to prevent hypothermia delaying extubation.

"OPCAB" or "Octopus" or "Platypus" This is a sternotomy without bypass with the heart stabilized by two arms with rows of suckers like octopus legs. Another retractor like a little footplate can also be used. A CO2 blower keeps the field dry while the surgeon operates. Both these techniques require improved technical skill on the part of the surgeon in that the heart is moving (contraction as well as respiratory movement). It also requires increased technical skill on the part of the anaesthetist because an area of myocardium is necessarily ischaemic. Haemodynamic instability and arrhythmias may occur. TOE and Swan Ganz are routinely placed to monitor ventricular function during ischaemic periods. The advantage of these operations is not yet proven. If surgeons and anesthesiologists can surmount the technical challenges (motion, bleeding, arrhythmias, haemodynamics, exposure) they offer great promise.

The equipment for MIDCAB/OPCAB is changing constantly. The 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 ischaemia caused by the stabilizing sutures or the reperfusion arrhythmias caused by releasing the sutures progresses to ventricular fibrillation?

Another problem with these cases is hypothermia. On-pump cases can be allowed to cool down pre-bypass because they are routinely rewarmed to 37deg prior to weaning from bypass. OPCABs must be kept warm with a "BAIR Hugger" or similar, preferably placed in the anaesthetic bay or even on the ward. Warming fluids may also help.

One plan for these cases is as follows:

Choose an anesthetic that lowers the heart rate as this will minimize the risk of myocardial ischaemia occurring during target vessel occlusion (fentanyl, alfentanil, remifentanil).

A perfusionist should be immediately available if required.

Positioning of the heart and placement of stay sutures / footplate may require preload adjustments. Fluids and /or vasoconstrictors are frequently necessary. Beta-agonists may produce pro-arrhythmic effects. The use of the Trendelenberg position is usually used to aid right ventricular filling.

Heparinize with 10,000 units rather than the usual 400 units/kg. Remember that if you need to go on bypass urgently, you MUST give additional heparin!  
Adjust the ventilator to reduce motion (small tidal volumes with increased rate).  
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. Glycopyrrolate or atropine are usually avoided to increase the heart rate as excessive tachycardia may occur.  
Be ready for reperfusion arrhythmias with release of the stay sutures.  
Reverse the heparin gently. Remember you don't have a bypass circuit ready to bail you out. Usually 50mg of protamine is enough.

Anaesthesia for Transmyocardial Laser Revascularisation (R. Wallace, P. Tralaggan)  
Usually via L) anterior thoracotomy if the sole procedure or combined with CAG.

Monitor with radial arterial line and PA catheter.  
TOE is needed to confirm laser "hits."  
Arms by side, saline bag under L) chest.  
External defib. pads  
Groin left uncovered for possible IABP insertion.  
Anaesthetic consistent with planned on-table (or soon after) extubation.  
Patient to recovery if extubated then ICU  
Further Reading :

Essentials of Cardiac and Thoracic Anaesthesia - Gothard and Kelleher - a very basic overview

Cardiac Anesthesia - Kaplan - more detailed, with an American accent!

Current Issues in Cardiac Anesthesia - Barash ed. - nice, concise supplement to 1. above

Cardiopulmonary Bypass - Gravlee et al.

Journal of Cardiothoracic and Vascular Anesthesia - THE journal.

Anaesthesia and Analgesia