

Cardiac Surgery Made Ridiculously Safe

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

Cardiac surgery is a dangerous and complex field of medicine with significant mortality. Proper anesthetic care with specific attention to detail can greatly enhance patient safety and can lead to disaster. This document will attempt to describe the bare bones sequence of CABG and VALVE procedures with specific recommendations. It is not all inclusive but includes critical requirements.

If you keep your head screwed on very tightly and pay 100% attention at all times the time.

A good reference is: Cardiac Surgery in the Adult by [L. Henry Edmunds, Jr., MD](http://www.ctsnet.org/book/)

An online reference text "Cardiothoracic Surgery Notes" for residents is available at <http://www.ctsnet.org/residents/ctsn/>

An online Johns Hopkins Cardiac Intern Survival Guide is available at <http://www.jhu.edu/~cardiac/>

Attendings:

Mark Ratcliffe, M.D. Elaine Tseng, M.D. Fellow: Ted Wright, M.D.

Rounds: M, T, W, Th, Fri, Sat, Sun

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Conference: Thursday 12:30 QI Meeting 203-3B-66

Friday 6:00 Rounds

Friday 7:00 Case Discussion 1C-Teak Room

Tuesday 4:30 Cath Conference: 1A-62

Thursday 1:30 Chest Conference MRI Conference Room Basement by MRI.

Clinic: Thursday 9-12:30

General Rules:

1. Call fellow whenever in doubt.
2. If you don't know, ask.
3. Never start or stop an inotrope infusion, without asking the fellow.
4. Do not transfuse blood products, without asking the fellow.
5. If a patient arrests start ACLS, and call the fellow.
6. Do not let a cardiac patient die with their chest closed.
7. Don't forget your ABC's.

8. In a code ELECTRICITY is your friend.
9. V-tach unstable or V-fib SHOCK-SHOCK-SHOCK epinephrine 1 mg, amiodarone repeat.
10. A-fib is common, rarely requires shock.
11. If the Fellow does not call you back, call the attending on-call.
12. When things get tough, or you can not get the SCUT done, ask for help,
13. I was too busy- is not the right answer.
14. All patients going to the operating room must have a CARDIOTHORACIC I filled out the night before surgery. If you don't fill out the note, the patient can't go
15. All patients going to the operating room must have either a fellows or an attending note, no operation.
16. All patients must have a mark on their operative site. No mark, no operation.
17. All patients must have a consent that lists their operation, No consent, no operation.

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ASSUME nothing: Assuming things makes an ASS out of U and ME. There are two things down, and those who forget.

Intern on call must:

1. Call consults early
2. Discharge patients early
3. Transfer patients from ICU
4. Check all new cultures
5. Take appropriate action on abnormal labs.
6. Keep the calls.
7. If you are called, go see the patient.
8. See the consults write a note and manage
9. note
10. Keep the 3X5 cards up to date.
11. Make a good scut list and get everything
12. post-call intern go home until you are certain you can do all the work on the scut
13. If there is a systematic problem with the service, ie order sets are wrong, this document out of date, notify the fellow and/or service chief to correct the mistake.
14. At chief will ask for a summary of the problems with the service. If there is a problem can be corrected. Thanks.
15. All patients going to the operating room must have PREOPERATIVE CHECKLIST note filled out the night before surgery. If you cannot go to the OR. No checklist, no operation.
16. All patients going to the operating room must have an attending note prior to going to the OR. No note, no operation.
17. All patients must have a mark on their operative site. No mark, no operation.
18. All patients must have a consent that lists their operation, No consent, no operation.

Preoperative Evaluation:

Patient Examination:

Pre-surgical evaluation must include attention to cardiac history. The cath report, information includes: Left main disease or equivalent, poor distal targets, ejection aneurysm, pulmonary hypertension, valvular lesions, congenital lesions. Past surgery they had surgery on a leg which may compromise the availability of vein graft harvest in the groin that will make balloon pump placement difficult? Each of these points technique and specific information is required. How is their angina manifest? Your verbal reports. If a patient's angina is experienced as shortness of breath, or nausea to be able to link that symptom to possible myocardial ischemia.

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

Past surgical history: Every operation they have had. If they have had surgery on mapping.

Allergies:

Medications : Look specifically for anti-anginal regimen - synergism between calcium channel blockers and beta blockers. COPD being treated? It is very important for patients to stay on their anti-anginal medications. If a patient is on a beta blocker, calcium channel blocker, nitrate, and/or ACE inhibitor throughout the perioperative period. The patient should get all anti-anginal medications following surgery. The day of surgery is the wrong time to go through a withdrawal. Withdrawing a single anti-anginal drug during the perioperative period is associated with MI, Stroke, renal failure, and/or death.

Physical exam: What was that scar from? Do they have leg veins for grafts? Are there any other findings?

Chest: Is the patient in failure? Pneumonia? COPD

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

Abd: Ascites, 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. Occasional patients 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? All patients for cardiac surgery

should be considered in any patient with an EF < 20%, or any re-operation with a history of cardiac surgery with questionable targets or a recent MI. Discuss with the attending prior to ordering. Dental Consult: We are trying to avoid operating on patients with dental abscesses, loose or broken teeth that can be dislodged by laryngoscopy. Obtain in all patients a chest X-ray (tube grafts, aortic root replacement), AICD or pacemaker, any implant.

Colonoscopy: We are trying to avoid severe GI bleeding after anti-coagulation. Perform a rectal exam, unexplained anemia, dropping hematocrit. For dropping hematocrit without hematuria.

Repeat all Work UP: Any patient with a recent MI needs a repeat CXR, ECHO, and ECG prior to surgery.

Notify attending and fellow of all significant abnormal results. Place all results in the chart. **Notify Attending for** 1) altered or abnormal LFT or albumin < 2.5. 2) Cr > 2.0. 3) WBC > 15K 4) Glucose > 300. 5) Positive U/A (leucocyte esterase positive with focal infection. If patient has a previous TURP or difficult foley placement discuss with urology place foley after induction of anesthesia

Presurgical: These patients are scared. They understand there is real risk. They are often anxious. At least 40% get ischemia preop with good premedication. Make sure they have a preop visit prior to surgery. Anesthesia will write for morning of surgery sedation. They need to eat and drink with a sip on night before surgery. They need to get all their medications except for those that are contraindicated prior to surgery. They need a preoperative note that reviews the case, describes the surgical plan, obtains consent, etc. All patients must have their surgical site marked with pen prior to surgery.

Medications Preop: All patients must get their anti-anginals. If the nurses put patients on the chart that patient is to get Drug X, Y, and Z with a sip of water at 6 AM. Other patients not needing their anti-anginals. Be incredibly clear in your preop orders or they won't get them. Omitting anti-anginal medications during cardiac surgery increases risk of death, MI, CVA, and stroke.

TEST/Therapy	Who	Abnormal	Value
Labs: lytes, BUN, CR, Glu, WBC, Plt, hgb, HCT, albumin, LFT, PT/PTT	All	Cr \geq 2.0 WBC \geq 15K Glucose \geq 300 U/A + LFT abnormal Albumin \leq 2.5	C
PFT:	All patients	FEV1 < 2.0	C
V/Q	FEV1 < 1.5 for lobectomy or < 2.0 for pneumonectomy	[if !supportEmptyParas] [e	C

		ndif]	
Erythropoetin + Iron	Jehovah's Witness	[if !supportEmptyParas] [e ndif]	C
U/A	All patients	Leucocyte esterase + and/or WBC > 5	I R C
Coronary angiogram	Everyone for CABG and valve	[if !supportEmptyParas] [e ndif]	[i ! s d
Vein Mapping	Previous leg surgery, previous CABG, abnormal leg.	[if !supportEmptyParas] [e ndif]	C
Radial Artery Ultrasound	Age ≤ 60, or no leg vein	[if !supportEmptyParas] [e ndif]	[i ! s d
Carotid Ultrasound	Age > 60, TIA, CVA, prior vascular surgery	velocity > 200 cm/sec, severe carotid stenosis, or a 75% or greater lesion,	C
Cardiac CT/MRI	Aortic calcifications,	[if !supportEmptyParas] [e ndif]	C b
ECHO	Everyone unless other assessment of LV function done already.	[if !supportEmptyParas] [e ndif]	[i ! s d
Myocardial Viability Study	EF ≤ 20% or EF ≤ 35% with redo	[if !supportEmptyParas] [e ndif]	C b
Dental Consult	All Valves or serious dental disease	[if !supportEmptyParas] [e ndif]	C
Colonoscopy	Guiaac +, anemia	[if !supportEmptyParas] [e b	C b

Intraoperative Care:

PA Catheters: At the present time all bypass cases get the standard monitors plus an article in JAMA that suggests PA catheters offer little additional information. As yet, this has not changed our practice. It is clear however that placement of PA without injury to other structures. With no proven benefit all risk must be reduced. ultrasonic mapping prior to catheter placement. Remove the towels from behind in the position you would like, then tape the head in place. Place the patient in Trendelenburg, draw out the anatomy, sternocleidomastoid, clavicle, carotid, etc. The more lines of ultrasonic goop is in place. Place the blue line in the center of the echo screen. Place the patient's right. Make sure the probe is absolutely perpendicular to the bed. If you have to take the angle into account and few can do trigonometry in your head. I've used a 5 MHz probe. Then take the 5 MHz probe and map out the path of the carotid and the IJ. The IJ is round and doesn't collapse under reasonable pressure. If you don't know how to do it, off the goop, redraw, and then map again. This technique requires the patient to be in Trendelenburg. I think this system is faster than not using the echo, as you waste 2 minutes searching with a needle.

Planning for Early Extubation: With the health care revolution this is the new paradigm in anesthetic technique that make it possible and a good candidate who is probably not simply that many patients appear to be good candidates and then aren't when they wake up with problems and do well. The simplest solution is to treat all patients as candidates until they qualify. Early extubation should be planned for in all patients because it requires a lot of care. The most successful candidates have reasonable cardiac and pulmonary function. The changes we have made include limiting fluid given to the patient, limiting benzodiazepine dose. Rely on volatile agents or propofol during the case. Provide a small amount of (propofol). Careful control of blood pressure with emergence. Remember some patients have hypoxic pulmonary vasoconstriction, increase shunt, and make weaning of FIO2 to 1.0 post op is critical. Then extubate the patient. Extubation time is controlled by how fast you want to extubate early, wean the FIO2 rapidly, wake the patient up, and when the criteria do it. It requires a cultural shift to accomplish. The most common reason for failure is mismatch (shunt) caused by heparin-protamine complexes in the lung. The second most common is sedation. Finally, hemodynamics, coagulopathy, etc. get on the list.

Communication: All information must be communicated to the surgical fellow or if you can't reach the fellow call the attending.

Hypotension: Hypotension with tachycardia is hypovolemia until proven otherwise. If the patient had good cardiac function coming off bypass and now is hypovolemic. If you have given volume, check the cardiac output, calculate the SVI. If the SVI is high, the CI is low (less than 2.0), and you are giving some inotrope, consider tamponade.

Tamponade: If the blood pressure is zero-open the chest. This is not like medication on the atrium, the heart won't fill, and the blood pressure will collapse. If the bleeding stops and the blood pressure drops- consider tamponade. Give volume, echo and a chest xray. A widening of the heart, fluid around the heart, low chest pressure - you should already be in the OR opening the chest.

Tension Pneumothorax: If the blood pressure is zero-open the chest. If the blood pressure is low, consider tension pneumothorax. The chest tube can be blocked with blood, or crimped. Check for bilateral 14 gauge angiocaths in the anterior-lateral chest at the T2-4 level.

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 \pm 10% of baseline. MAP 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 bypass and between 60-80 during warm bypass (cross clamp off). There will be exceptions for severe aortic disease or chronic renal insufficiency that may need higher pressures (60-80 mmHg).

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

Fluids: There are lots of theories on fluids and little data to support the strongly held belief that patients suck up large amounts of fluid intraoperatively with little obvious benefit. All of the fluid given postoperatively frequently by administering large amounts of lasix with subsequent diuresis. Postoperative extubation is frequently delayed by intraoperative fluid administration. Limit fluid administration intraoperatively. A few suggestions. If you have two large bore IV lines, give 500 cc of LR prior to bypass. Do not administer any fluids during bypass except for drugs. Use hespan post bypass up to 20 cc/kg, then shift to albumin. If you use heparin, use heparinase.

not apply. If the patient has previously had 20 cc/kg of starch (hexend or hespan) metering device on any carrier lines to prevent accidental high flows. Use neosyr giving large amounts of fluid prebypass.

Fluid Tallies: Tally the estimated blood lost, and fluids administered including pump blood, bypass prime volume, and total fluid given by perfusionist on your efforts where we ignored everything but the crystalloid, colloid, given by anesthesiologists and perfusionists. The perfusionists can give large amounts of crystalloid and we should know about it if they give hespan or hexend in the pump prime we should know about it.

Ischemia: Patients have CABG surgery because of myocardial ischemia. 40% of patients have intraoperative episodes of myocardial ischemia. You should record a 5 lead ECG comparison. Ask the patient if they are having chest pain at this time. You should check at least every 60 seconds and ask - What is the rhythm? Is there ischemia? Only if you detect a substantial fraction of the ischemia.

When the blood flow to myocardium is insufficient, it immediately stops contracting. At 60 to 90 seconds the ECG ST-T wave starts to change. This focal reduction in wall motion is seen when watching the ECHO image. The best level is a short axis mid papillary view. You should have a long axis mid papillary view for comparison. The ECHO is an adjunct to care not a replacement when looking at the echo.

Clotting: Cardiac surgical patients receive a lot of heparin (300 to 400 U/kg = 20 mg/kg) and protamine. The protamine and heparin make a weak salt which is cleared in the liver. If the patient has protamine, the patient can become re-heparinized post operatively. Check the PT/PTT. If elevated give more protamine (25-50 mg). The anesthesiologists gave protamine so you are adding to the dose. Protamine is an evil, wicked, dangerous drug made of fish. It can cause profound vasodilation from histamine release. It can cause a hypertensive response. Treat it as the most lethal drug you will administer and you will not be ready to treat hypotension from profound vasodilation (neosynephrine or epinephrine).

Sternotomy: Painful process that occurs rapidly after induction, make sure the patient is on anesthesia to let the lungs down during opening. Develop a system to prevent you from coming 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 together. The surgeon may cut through the right ventricle with resulting (profound) hemorrhage. Blood may also cut through the IMA or a saphenous graft. You should have an idea of what to expect from the report and a plan. Instant severe myocardial ischemia with rapid deterioration means the native heart and grafts are not functional. Functional grafts that the patient is dependent on is a good thing. Knowledge of the chest xray (pa and lateral), prior operative report with details c

are essential to decide on how to handle these situations.

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

Heparinization: Do not go on bypass without heparinization. If the patient is not on the bypass pump, the pump and oxygenator will clot and the patient will most likely die. In some arteries give the heparin. When you ask for heparin, require a verbal reply. The dose of heparin is 300 U/kg which is about 21 cc of 1000 u/cc heparin in a 70 kg patient. After the dose. If the patient is on heparin preop, give the same dose (Heparin 300 U/kg). Just be careful putting in lines. Do not give anti-fibrinolytics until fully heparinized. Wait at least 450 seconds after the dose, give more, until the ACT is above 450 seconds. ACT must be above 800 seconds. If a kaolin ACT is used the normal 450 second ACT. Add heparin to your ACLS protocol for cardiac surgery patients. If the patient cannot be put on bypass for resuscitation.

All patients getting cardiac surgery using extracorporeal circulatory support should have several choices. It may be that all should get aprotinin, unless given in previous cases. It 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. Without risk factors they get amikar. If they are a redo case, a case with renal failure or a Jehovah's Witness where bleeding would be lethal, they get aprotinin.

Amikar: Epsilon amino caproic acid used as an antifibrinolytic. Some evidence that it works. Some clinical reports of problems (left ventricular thrombus, arterial thrombi, etc). Give 5 g IV before bypass and 5 g IV after bypass. Can be given in higher doses 10 g prior and 10 g after. More expensive (\$12/bottle) than aprotinin (\$900/bottle) although the efficacy is not proven. No convincing safety data. We are using it on all cases. Give 5 g IV slowly after protamine is in. You do not want to give it prior to protamine. Give 5 G IV slowly after the protamine is in. You do not want to give it prior to protamine. Associated with protamine administration and it is easier if only one drug can be used.

Aprotinin: Antifibrinolytic and platelet preserver that reduces bleeding and transfusions. Used in redos and people on aspirin. Costs \$900/case. The transfusions for a case average 10 units. If one considers the risk of disease transmission from transfusions aprotinin is a good choice. Reduces risk of graft closure from clotting. If one looks at the morbidity and mortality associated with transfusions aprotinin reduces risk of death. It is allergenic so patients should probably only have one unit. It is probably best for a redo CABG.

Our present use is for REDO CABG, patients with renal failure, patients with risk factors where bleeding would be lethal (Jehovah's Witness). Order 6 M units (3 200cc bottles a case). Give 20 cc over 20 minutes starting prior to skin incision. Then continue at 10 cc/hr.

with 2 M units so give one bottle to them. I have tried to avoid using a fourth bottle to 0.3 to 0.4 M U/hr so that the infusion bottle will last until the end of bypass. Lower infusion is probably reasonable. Remember celite ACT 800 seconds, kaol

What operation are we doing today?: Cardiac surgery used to be done using extracorporeal circulation. We did CABG without the pump but it was rare and usually done elsewhere. In the last 20 years, the use of bypass surgeries done using off pump techniques has risen dramatically. The invention of off pump techniques is easier, safer, and practical for most CABG operations to be done off pump. At the end of the day, it is up to the patients to "on pump" versus "off pump" care. If the decision seems random, you are probably wrong. The two approaches are fundamentally different for these two approaches so we will separately discuss them. We will focus on the "OFF PUMP" approach. You need to be flexible because they can change the

Placing the cannulas:

Do not go on bypass without heparinization. The arterial pressure at this point should be 80-90 mmHg. The cannula in the aorta (has a red tape on it) should not have any bubbles in it. Check the venous 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 ventricle. It is a drain line and may have bubbles. On mitral valve and ASD/VSD cases, the cannula goes into the superior and inferior vena cava.

The small cannula with a balloon at one end is placed into the coronary sinus through the right atrium. When the flow in the coronary sinus cardioplegia line is 200 ml/min the pressure in the coronary sinus is like CVP and does not go up with coronary sinus flow (retrograde cardioplegia). If this happens during continuous warm cardioplegia, there is a problem. If the pressure is very high (greater than 20 mmHg) the cannula is against the wall and you also may not be having good retrograde flow.

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

Check List for Going on Bypass:

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

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. 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. A system can cause the loss of the siphon. If the perfusionist notes bubbles on the venous line, the integrity of the cordis, closure of all stop cocks, the surgeons will check the atrial pressure temporarily the venous pressure will rise and the air leak will diminish. The lines are checked for airlock occurs.

Cardioplegia: There are lots of types. Cold, Warm, Warm induction - Cold Mannitol Shot, Crystalloid, Blood, Antegrade, Retrograde. The best is a short cross clamp. Record the on bypass time, the off bypass time, the on cross clamp, the off cross clamp. After 1 hour ventricular function deteriorates, as it exceeds 2 hours it gets worse. Cardioplegia are lots of things added to cardioplegia and the bypass prime and you should find out what they will say something like "Nothing special" which translates into potassium, mannitol, bicarb, adenosine, free radical scavenger of the day, and snake oil. Ask the perfusionist in the cardioplegia bag, most of it only in the eye of the orderer. If something went wrong (potassium to 30, potassium sky rockets, glucose is very high) consider what is in the cardioplegia.

De-Airing Maneuvers: It is bad to pump air to the patient. It is difficult to get all the air out of the middle cerebral artery during bypass demonstrate 50-2000 emboli per case. It is caused by atherosclerotic plaque. The smaller the bubble the bigger the echo signal. On open heart surgery surgeons will have you place the head down. Then they will bump the patient, rotate the patient, aspirate from the aorta, etc. in the hopes of getting out all of the bubble. If you want. If you look at the echo at this time there will be a snow storm of little bubbles. One or more than usual say something.

The majority of emboli occur on aortic cannulation, cross clamp placement, cross clamp removal, weaning from bypass, and aortic cannula removal. It is best to keep the patient at normal temperatures (37°C) during any of the embolic times. 95% of patients suffer 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 monitors.

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 before? What was the cross clamp? What does the heart look like now? What is the resistance now? Or ask the surgeon. If you plan to use a drug with prolonged side effects ask them what they may have an opinion that should be considered. Have some inotrope ready. You can't wean CABG patient's from bypass with no inotropes. Calcium chloride is commonly been associated with pancreatitis.

A standard weaning plan would be to calculate the systemic vascular resistance (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 if you develop a reasonable pressure post bypass will be too high. Vasoconstrictors (phenylephrine) have some vasoconstrictive effects (dopamine, epinephrine, norepinephrine) are commonly used at reasonable levels. Here is an example. The MAP is 50 and the CVP is 10. You are using a 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. The SVR will be 640, the MAP will be 50 and the BP will be 95/50. The patient is in cardiac in nature. The problem is simply low resistance. An inotrope is not needed.

If the SVR had been raised to 1200 prior to coming off pump, the 5 liter/min cardiac output 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, the patient will be lousy and an inotrope will be necessary. If the inotropic state of the ventricle is 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, Ventilation Adequate, and Urine Output 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 throughout the body. The large plastic pipe is full of fluid and hooked to the venous system. The large clamp is placed on the inferior vena cava. Note: Before attempting any of this activity, (not recommended in the classroom) ensure you have fulfilled the criteria for going on bypass (HARDSUE) or coming off bypass.

NEVER LET THEM GO ON PUMP IF YOU HAVE NOT HEPARINIZED

very reassuring but not absolutely essential in dire and I mean dire emergencies. must be greater than 450.

The simple explanation for going on bypass is the perfusionist removes the clamp, the siphon effect drains blood from the right atrium and inferior vena cava into the venous reservoir. The perfusionist maintains the siphon effect to keep this flow going. Since, there is no or less blood flow, the patient's cardiac output drops. The perfusionist then turns on the pump and returns the blood to the patient's aorta. If all is working well the blood will be heated/cooled and oxygenated before being pumped through the filter and back into the aorta. Unclamping the venous reservoir increases venous pressure and diverts blood into the pump. The perfusionist will say something like "4 to 5 liters a minute of venous drainage and are able to pump 4 to 5 liters/min into the pump." The perfusionist will also monitor the patient's oxygenation 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: patient is warm, the heart is beating, the monitors are turned on, the ventilator is set to an appropriate resistance and inotropic state to an appropriate level. The perfusionist then partially unclamps the venous reservoir, reducing the amount of blood draining into the venous reservoir. The right atrial pressure increases, pushing blood into the right ventricle and out the pulmonary artery. At this point you can have a partial bypass. The perfusionist reduces systemic blood flow with the rest produced by the heart. The surgeon will say something like "reduce flow to 4 liter/min." You will notice that the pulmonary artery and systemic pressures both decrease. The perfusionist will say "2 liter/min then 1 liter/min." They are watching the right and left ventricles to ensure they are not overloading. They also watch the pressures and slowly load the heart. When they say something like "stop," the perfusionist tells the perfusionist to leave 100 cc less blood in the reservoir. The perfusionist then stops draining blood from the patient and pumping 2 liter/min to the patient. They are supposed to be able to stop the pump if 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 on bypass. The venous cannula. If you have a kind surgeon, they will place it in a bucket of saline to keep the line full of saline. This allows the perfusionist to start heparinizing but keeps the venous line ready in case you have to return to bypass. The arterial line can give fluid. When the patient's blood volume is low you will hear - "give a hundred cc." The perfusionist unclamps the arterial line with the pump on and drains 100 cc of fluid from the reservoir. The perfusionist then tells the surgeon to unclamp the arterial line. Who weans the patient from bypass and who gives volume orders? This varies by institution; the anesthesiologist does at others the surgeon does. If you are not reassured, think the patient needs to go back on bypass, tell the surgeon to put the cannulas back in. If you need more volume, ask for it. In cardiac surgery where it is essential that you be able to tell the surgeon what to do, and w

communication is key. It is essential that it is a team process. They need to know something is not working, they need to know about it. They can and will most like

Inotropes and Vasoactive Compounds: If you are using a drug that requires an incorrect or fluctuating dose would be difficult to manage, use an infusion pump. epinephrine, norepinephrine, nitroprusside, nitroglycerin, neosynephrine, and pro relying on gravity drips are unacceptable. Gravity is reliable, back pressure is not concentrations approved by the pharmacy. The labels with the appropriate conce anesthesia machine. If you mix it and label it with the yellow label then the ICU get to the ICU. If you mix some weird concentration, label it poorly, or then put i away your drugs and the patient will get less than optimal care.

Drug	Alpha	Beta	Dopamine	PDE-I	NO	MAP	HR	CO	SVR
Phenylephrine	++					+	±	-	+
Ephedrine	+	+							
Norepinephrine	+++	++				+++	-	±	+++
Dopamine	+	+	+			+	+	+++	+
Dobutamine		+				±	+	+++	-
Isoproterenol		+				-	++	+++	-
Amrinone				++		-		+	-
Milrinone									
Nitroglycerine					+	-	+	-	-
Nitroprusside					+	-	+	+	-

Prophylactic Drugs: Some surgeons believe that prophylactic high dose steroids reaction to bypass or reduce neural injury. Scientific evidence for these theories i infections and poor wound healing. Some surgeons believe in prophylactic inotr prophylatic nitroglycerin infusions have been suggested as a preventative measur ischemia, downside is hypotension, supply limited ischemia, and more fluid requ Magnesium is thought to be an anti-arrythmic, anti ischemic agent. Some people surgery (2 grams IV) others do not. The scientific evidence for many of these the have to communicate and ask your surgeon their preference. You will have to co professional compromise on prophylactic drug use.

Phosphodiesterase Inhibitors: Do not start a phosphodiesterase inhibitor (Amri cardiac surgeons. Do not choose it as first line inotrope. A phosphodiesterase inh 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 a

High potassium depends on timing. Greater than 5.0 is common on bypass from below 5.0 but greater than 4.0 when you come off pump. The perfusionist can ultimately
Hematocrit: Drops with the hemodilution of the bypass pump. If it is below 20 you need to use clinical judgment. Talk to the surgeons, they may have an absolute rule to 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 what everyone will be happy. If it is greater than 120 mmHg the patient is hypertensive. Cardiac index greater than 2.0 is fine. Pa Diastolic less than 20 mmHg, CVP less than PAD there is a problem: poor calibration or right ventricular failure. Always check 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 histaminic responses. Protamine 10 mg will equalize Heparin 1000 units. Protamine comes as 10 mg per cc of protamine will neutralize it. You are forming a weak salt between a base and an acid response. You need to give the dose and then check the response by measuring the shunt post op is caused by clearance of heparin-protamine complexes by the reticuloendothelial system.

Protamine Administration: Give 10 mg = 1 cc peripherally and check for allergic response: bronchospasm, rash, or pulmonary hypertension. Stop administration for problems with protamine, be ready with phenylephrine. Steroids, H1 & H2 blockers, vasoconstrictors can help. Allowing the heparin to spontaneously be metabolized is another option. Then give the rest of the dose slowly. What is slowly? If you follow the PDR it varies, at some institutions it would be 1 minute. Over 20 minutes is not unreasonable. Once off bypass perfusionist so that they can stop the pump suckers and avoid clotting the pump. If you do not 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 not give more protamine. If you give pump blood after this point you may only find this out by measuring the ACT. Check the ACT after you give blood product.

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

Returning to Bypass: If there is severe hypotension, bleeding, low cardiac output, return to bypass. If you have given the protamine, give another dose of heparin after the aortic cannula is removed, you should make a decision about whether you may be having severe problems maintaining the pressure despite inotropes, tell the surgeon to return to bypass or immediately return to bypass. It is very bad for the heart to be dilated.

low coronary perfusion pressure. You may have to return to bypass.

Balloon Pump: Very nice system for inadequate left ventricular function. The balloon pump sends an arterial pressure signal. On the Datex monitor the slave cable plugs into channel 3. Plug the CVP cable into channel 4 and change the label on channel 4 to CVP. The easiest thing to do is to get a new pressure transducer. Hook the new arterial transducer cable into channel 3. Change the label on channel three to ABP. This will make it easier to plug the slave cable into channel three and send it to the balloon pump. There is also a way to look at external ECG and arterial pressure from the slave cable. Both settings may suggest if there is difficulty weaning from bypass.

LV Assist Device: Transportable centrifugal pump that can be used as a bridge to wean from severely stunned myocardium.

Closing the chest: May cause hypotension if inadequate volume status. Check a trial of chest closure. If seem too large or the heart is lifting out of the chest, consider bronchospasm with a trial of intubation and ETT adjustment can help.

Transport: Have the patient monitored at all times. Never remove the ECG until the OR leads, get it to work, then remove the OR leads. Do not change the A-line if hemodynamically stable. If you elevate the transducer 13.6 cm you will reduce the arterial pressure 10 mmHg. 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 drop from the operating table to the bed. This phenomena is not well understood but may be related to the tissues with the shift to the bed. The patient can have profound hypotension. Most commonly noticed. Have volume available. Do not make the shift if the patient is unstable prior to the shift. Have volume, some drug to raise the pressure, some drug to lower the pressure. Other drugs you have been using with you on transport.

ICU: Shift the monitors in the same way. The cartridge for the transport monitor may not work. If you don't have this system get the ICU ECG working before removing the transport monitor. The patient is hemodynamically stable. Listen to the chest immediately after hooking up the ventilator. If hypotension suspect a problem the ventilator (infinite PEEP) and remove the patient from the ventilator. Then get a new ventilator. Do not allow the nurses to change to their own ventilator. 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 respiratory failure, Hemodynamic stability on limited inotropic support, (no balloon pump or other support), limited bleeding without a coagulopathy (chest tube output < 100 ml in 4 hours), good gas on FIO₂ is 0.40, SIMV 8, PEEP 5, TV = 10 cc/kg, the patient is stable on CPAP 5 cm H₂O FIO₂ = 0.50 then extubate. Talk to the surgeons about your plan.

why this patient is a lousy candidate (The grafts were poor, there is bleeding, the

Cardiac Surgery for Minimally Invasive Surgery: Off Pump CABG

I guess the first question should be what to call this new operation. It is minimally invasive CABG. Maximally difficult CABG. I don't know. A little cabbage is commonly known as a difficult operation is changing rapidly. This is now a history to how it was done. That in Initially, there was the Heart Port operation. The marketing plan of the Heart Port operation was to avoid a sternotomy scar. Most people coming for a CABG are past the age when the scar case of Bay Watch. The operation was simple, no that's not right. An arterial inflow catheter and the venous outflow was placed through a femoral vein. A catheter with a balloon inflated in the ascending aortic arch. Aortic atherosclerotic disease was a concern in this operation. Picture sliding the catheter up a severely diseased aorta followed by cardioplegia. Cardioplegia was then delivered antegrade to the coronary arteries which have been occluded by circulation by the ascending aortic arch balloon. A catheter was advanced from the pulmonary artery for venting the left ventricle. The patient was placed on fem-fem bypass. A single vessel CABG was then performed either through a mini thoracotomy or a mini sternotomy. This operation is obvious. The risk from with a CABG is the extracorporeal circulation. The major morbidities of CABG surgery is the neuropsychiatric changes and strokes. The fem-fem bypass run for a single vessel CABG. It maximizes the risk of stroke while eliminating the risk of stroke was doomed to failure from the start.

CTS (Chuck Taylor Surgical or Cardio Thoracic Surgical) and US Surgical work was developed by Bennetti. It was in essence a mini-thoracotomy with no bypass. The standard CABG was stabilized by placing latex sutures under the LAD proximal and distal to the bypass. The sutures presses on the myocardium while the sutures pull the heart into the foot. Blood flow is maintained by the stabilizing sutures. The technique requires improved technical skill on the part of the surgeon and the anesthesiologist (contraction as well as respiratory movement). It also requires increased skill from the anesthesiologist because an area of myocardium is ischemic, and non-functional. The advantage of the operation is reduced cost (no extracorporeal circulation, reduced risk of stroke (no extracorporeal circulation). If surgeons and anesthesiologists can master the technique (motion, bleeding, arrhythmias, hemodynamics, exposure) it offered great promise. The operation is difficult and inferior wall vessels were hard to approach.

Octopus and Starfish. These retractors use suction to stabilize the heart. Instead of the CTS system, the Octopus system sucks up the myocardium with two little arms. It tightens the area and reduces motion. The Starfish is a retractor for lifting and moving like a Y. With these retractors, hemodynamics are much improved during stabilization. The equipment for MID-CABG is changing constantly. The fundamental problem to address is what is the plan when the patient has ventricular fibrillation. If the surgeon performs a thoracotomy, what is going to happen when the ischemia caused by the stabilizing device, caused by releasing the sutures, progresses to ventricular fibrillation? The second question is, despite the efforts of the surgeon,

My favorite plan is this.

1. Choose an anesthetic that lowers the heart rate (fentanyl, sufentanyl, alfentanil).
2. Use a median sternotomy approach. The morbidity is small compared to the right thoracotomy. Have the perfusionist available. Don't prime the pump but have it completely set up. The lines just be ready. If you can't convince the surgeon to do the case as a sternotomy, be ready for an emergency sternotomy when the patient fibrillates. The other advantage of the sternotomy is that multivessel CABG without extracorporeal circulation is possible. With the mini-thoracotomies, mini-thoracotomies are needed for the second and third distal anastomosis. If you end up with mini-thoracotomies, consider using a double lumen tube for better exposure. The
3. Anti-coagulate the patient just as you would for a CABG with extracorporeal circulation. If it is a problem, it is easy to cannulate and go on pump.
4. Prophylaxis for arrhythmias with your favorite drugs. Magnesium 2 gram IV plus calcium infusion at 2 mg/min. I am a strong proponent of amiodarone (IV). If you have a 10-minute infusion, 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 (hespan / hextend) and maintain the pressure with vasoconstrictors. I try to avoid tachycardia and pro-arrhythmic effects. Tachycardia makes the anastomosis more difficult. Adjusting hemodynamics only to have all your work reversed when the heart is released. Trendelenburg is very useful for inferior wall distal anastomosis.
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). Use atrial pacing. Do not use glycopyrrolate or atropine when asked to increase the heart rate. Be ready to undo when the surgeon changes his mind.
8. Be ready for reperfusion arrhythmias with release of the stay sutures.
9. Reverse the heparin gently. Remember you don't have a bypass circuit ready to go. Protamine may be reduced because of the lack of damage to the platelets. Check

the protamine to avoid overdosing.

10. Consider anticoagulation post reversal of protamine. CABG surgery benefits coagulation system. When was the last time you saw a post CABG pulmonary embolism? In a Off Pump-CABG where the coagulation system is normal. All of the problems with pulmonary embolism that the vascular surgeons have will now occur with cardiac surgery. If you have a night trip to the OR to remove the clot for vascular surgeons. Off Pump CABG can be a cold blue patient and a trip to the morgue. Be very, very, very careful about post CABG anastomosis was done in less than optimal circumstances (movement, bleeding, low flow, system is fully functional. We are trying dextran infusions to try to have some protection against bleeding. The jury is still out though.

We have had thirty years to figure out all the tricks for normal CABG's. The Off

Post Operative Care:

Most important things to watch for on a fresh post-op Heart patient.

1. **Bleeding: What is significant bleeding?**

Chest tube output >200 ml/hr x 4hrs, greater than 1000 mls, or sudden 400 mls.

2. **Low Cardiac output CI <2.0: What should you consider?**

- **Tamponade:** not like medical tamponade, can be pressure on atrium. If the chest blood pressure drops despite volume, and the central venous pressure and pulmonary pressure are elevated (greater than 20 mmHg), you must consider tamponade. Get a chest X-ray of the mediastinum. Get an echo. If you have started 2 inotropes, and given volume (greater than 2.0), you must rule out tamponade.
- **Hypovolemia:** The diastolic function of the ventricle is stiffer than normal, the ventricle is not vasodilating. Hypovolemia is very common. What did the anesthesiologists do to extend if they gave more than 20 cc/kg. Give albumin if the hematocrit is low.
- **Cardiogenic Shock:** If the patient was stable coming off pump (IE no or minimal pulmonary edema) consider why they are now in cardiogenic shock. It is more common to have poor systolic function in a patient that was ok coming off pump. Call your fellow cardiologist, get an ECG, get a CXR, rule out other problems.
- **MI:** We just revascularized the heart but plaques can rupture, grafts can clot, and inotropes all can lead to MI. Troponin I levels less than 10X the upper limit of normal are probably myocardial infarctions. The higher the troponin I level

3. **Low urine output**

- hypovolemia: anemia hct. <25% under resuscitated bleeding
- lasix defficiency: pod#1-4 lasix unless prerenal {BUN>30, Cr>2.0}

4. **Atrial Fibrillation is very common**

cause; fluid, electrolyte, hypoxia, Pulmonary emboli, MI

Treatment:

digoxin load

diltiazem iv

any other drug tx call fellow

Pacemaker:

wires left in AVR for 72 hrs

Wires left in CABG or MV for 48 hrs

You must inform the RN and have patient on telemetry before you pull wire. WF

Do not ever leave a patient in DOO or VOO mode.

Thoracic Surgery Patients

1. They are different than cardiac surgery patients

2. Chest tube management

Suction or Water Seal

when to pull tube?

Usually 24hrs on Water Seal no airleak and less than 150cc per 24hrs before con

3. Keep most patients DRY

especially pneumonectomy

4. Pain control very important

5. Pulmonary Toilet

6. DVT Prophylaxis Heparin 5000u SQ bid.

7. DC f/u need CXR PA & LAT pt must bring the film to clinic

8. Bowel Care important, ileus can be severe.

Pre op of Lung Cancer patient

1. What is the type of Tumor? What treatment have they had?

2. CT of chest

3. PFT's

4. Old or h/o of Heart Disease

5. Stage of tumor

bronch results

medianstinscopy results

6. If FEV1 <1.5L get quantative V/Q scan
7. R/o metastatsis, consider PET scan
8. Bowel prep MgCitrates 1 bt.

3x5 cards

1. Stamp with Patient's card
2. referring MD's name, address or phone, hospital
3. operation or diagnosis
4. big events during hospitalization

Good Luck: You should enjoy your rotation at the VAMC. You will get a reason for surgery. If there are any comments, changes, additions, errors in this text, I, Art Wallace, is very important for this document to be an accurate reflection of the service as it is. If there are mistakes, it will get out of date and be useless. Please, if you find an error or need maintenance, notify me as soon as possible. Please e-mail me with suggestions.
by [Art Wallace, M.D., Ph.D.](#)
