

# Off-pump Coronary Artery Bypass Grafting

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## INTRODUCTION

**T**he advent of cardiopulmonary bypass in the early 1960s allowed surgeons to safely perform complex operations on the heart.

Since then, the field of cardiac surgery has progressed to where coronary artery bypass grafting (CABG) has become the most methodically studied operation in the history of surgery. It has achieved widespread use, because its benefits have been documented so thoroughly. The procedure's adverse effects also have been recognized from the beginning and are well documented.

After 40 years of technical and surgical evolution, however, the approach to coronary artery surgery has remained basically unaltered—until the past decade.

### U.S. STATISTICS

In the United States, approximately 400,000 open-heart bypass surgeries are performed annually, according to the American Heart Association. The patient population is growing increasingly higher risk due to more catheter-based intervention, the rise in diabetes, and the continued unhealthy lifestyle of a majority of the American population.

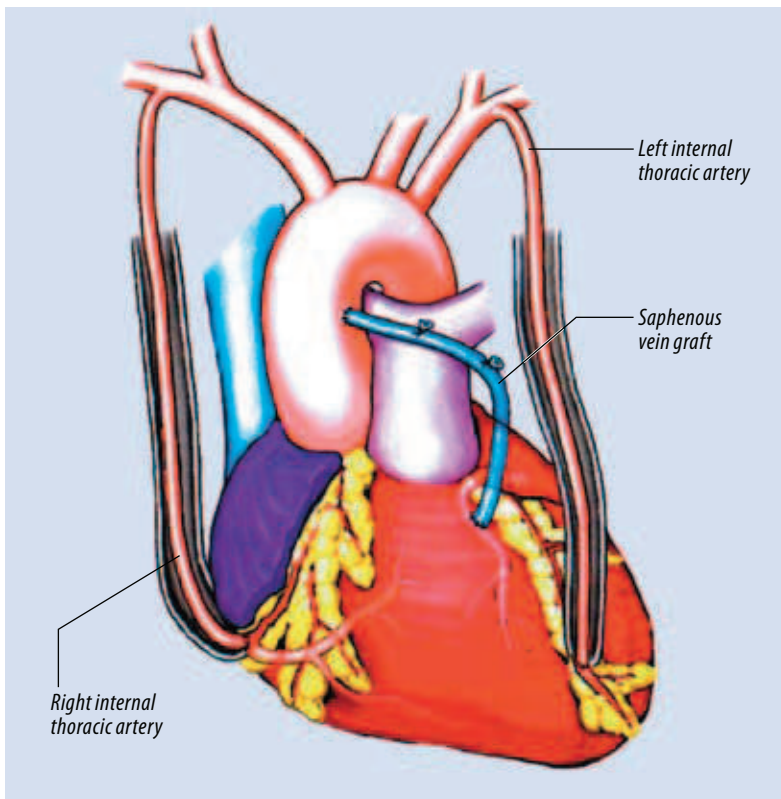
Therefore, the need arises to conquer the beast of coronary artery disease in more innovative ways that enable patients to recover faster and have fewer complications than conventional approaches provide.

### HISTORICAL PERSPECTIVE

1953: John Gibbon, MD, performs the first successful open-heart operation using a cardiopulmonary bypass machine.

1967: First off-pump procedure performed—An anastomosis of the left internal mammary artery (LIMA) to the left anterior descending coronary artery (LAD) for treatment of angina pectoris.<sup>1</sup>

**Figure 1:** Internal mammary (thoracic) artery and saphenous vein anastomosed to coronary arteries.



1995: First off-pump coronary artery bypass (OPCAB) procedures performed for multivessel coronary artery diseases.

2007: Nearly 40% of all coronary artery bypass graft (CABG) procedures are performed off-pump.

*“Every place that does cardiac surgery needs to be in the off-pump CABG (business),”*

*Peter Knight, MD, cardiothoracic surgeon and director of robotics, University of Rochester, Rochester, New York.<sup>2</sup>*

### RELEVANT ANATOMY

The heart, being a living organ, needs oxygenated blood flow to maintain muscle viability. The coronary arteries fulfill this need.

The coronary arteries originate in the sinus of Valsalva in the proximal aortic root. They are divided into left and right main ostiums.

The left main trunk branches into the left anterior descending (LAD) and the left circumflex arteries. The LAD gives rise to a diagonal branch, and together these vessels supply the anterior wall of the heart, along with the septal wall perforators.

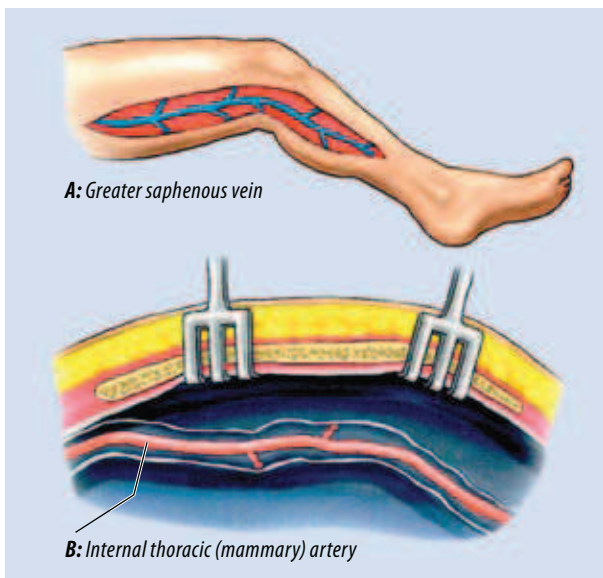
The left circumflex artery wraps around the back side of the heart and divides into the obtuse marginal (OM) branches. In most cases, there are at least two OM branches that supply the posterior and anterior lateral walls of the heart. (Figure 1)

The right main coronary artery wraps around the right side of the heart and gives rise to a left ventricular branch and a posterior descending artery. These branches supply the right and posterior walls of the heart.

### PROCEDURAL BENEFITS

The debate between the benefits and risks of off-pump CABG surgery continues to be challenged by the advent of new stabilization equipment, intravenous medications and more case experiences.

Off-pump CABG offers benefits to several types of high-risk patients:



**Figure 2:**  
Graft options for CABG: A: Saphenous vein dissection and (B) Internal mammary artery dissection



**Figure 3:**  
Aortic punch

Figures 1–3 reprinted from *Surgical Technology for the Surgical Technologist: A Positive Care Approach*, Delmar Cengage Publishing, 2nd edition. Copyright 2004.

- Patients with calcified aortas—In conventional CABG, the aorta is clamped. If the patient has any calcification in the area that is clamped, the risk of embolization and stroke is significantly increased.
- People of the Jehovah’s Witness faith—People of this faith often object to blood product transfusions. Therefore, to reduce bleeding and minimize the need for blood products, off-pump CABG offers a reduced risk of morbidity.
- Patients with a history of cerebral vascular accidents
- Patients with renal failure, severe diabetes mellitus and peripheral vascular disease—These patients have an increased risk of adverse reactions when placed on cardiopulmonary bypass.

By reducing use of the heart-lung bypass machine, many of the risks of conventional CABG are likewise reduced, including:

- Systemic inflammatory response
- Full heparinization
- Embolism
- Postoperative bleeding
- Aortic dissection
- Ischemic cardiac arrest
- Coagulopathies due to platelet damage
- Hemodilution

- Extended bypass times
- Transfusions and the need for blood products

Other benefits to performing the procedure without the bypass machine include:

- Shorter hospital stay
- Less cognitive dysfunction (caused by a systemic response to the nonphysiological effects of the cardiopulmonary bypass machine<sup>3,4</sup>)
- Reduced inotropic use

#### PROCEDURAL RISKS

OPCAB’s risks include a steep learning curve, arrhythmias, bleeding, and ischemic changes.

Any new approach to surgery requires a learning curve for the entire team. The ideal patient for learning OPCAB is one with normal heart function who requires two to three grafts.

Arrhythmias, such as tachycardia, bradycardia, ventricular fibrillation and asystole, may occur during an OPCAB procedure. All of these arrhythmias can be controlled by medication or by cardioversion.

With any surgery, bleeding can be a risk. Due to reduced heparinization, hemodilution and O.R. time for OPCAB, the risk of bleeding is minimized.

Ischemic changes may occur as a result of occluding the target vessel. This risk can be reversed by placing a shunt inside the target vessel. This restores blood flow through the vessel and allows the team to continue the procedure.

#### TOOLS FOR SUCCESS

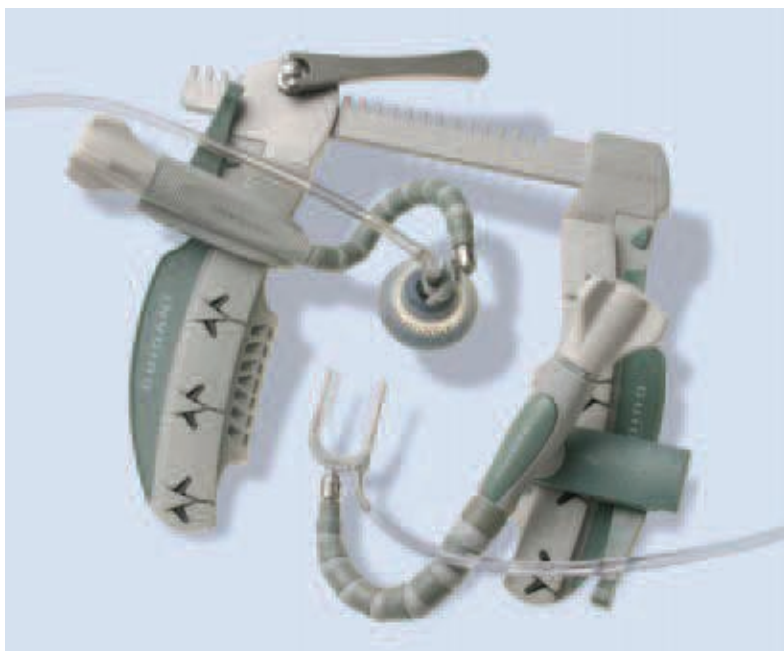
The first step in achieving successful results is to form a team that is dedicated to learning and teaching OPCAB techniques. The team should consist of a cardiovascular surgeon, an experienced anesthesiologist or nurse anesthetist, a circulating nurse, a perfusionist (on stand-by), a first assistant and a surgical technologist.

All team members must be able to handle high-stress scenarios and must know their roles when cardiac resuscitation is required. It is also very beneficial to discuss successful and unsuccessful events, techniques or products used during the case.

The next tools are mechanical. Our facility chooses to use the ACROBAT<sup>®</sup> off-pump retractor and XPOSE<sup>®</sup> device. (Figure 4) These devices use controlled suction in order to stabilize and maneuver the heart.

We also use retractor tapes to occlude the vessel and FloCoil<sup>®</sup> shunts, if necessary, to restore coronary blood flow during the anastomosis.

**Figure 4**  
ACROBAT<sup>®</sup> SUV  
Off-Pump System



In addition, our facility uses the AXIUS<sup>®</sup> Blower/Mister for visualization of the coronary artery. (Figure 5)

#### PROCEDURAL OVERVIEW

The patient is brought to the operating room with an IV already in place and then receives sedation. Anesthesia personnel insert a radial arterial line and a Swan-Ganz catheter in the external jugular, and then place EKG leads.

The nursing staff places a Foley catheter and bovie pads and then positions the patient supine with legs frogged and supported and arms tucked to the side. A Hibiclens<sup>®</sup> scrub is performed, followed by ChlorPrep<sup>®</sup> or DuraPrep<sup>™</sup> skin preparation solution.

Sterile towels are placed between the legs. Ioban drapes are applied, followed by the chest sheet.

A median sternotomy is required for single- or multiple-vessel grafting for both off-pump and traditional CABG. A median sternotomy allows access to all potential targets, including routine access to the right (RIMA) or left (LIMA) internal mammary arteries for harvesting. The procedure also allows rapid institution of CPB should instability occur during the procedure.

A partial sternotomy can be performed for ante-



**Figure 5**  
AXIUS<sup>®</sup> Blower Mister



**Table 1. Agents commonly administered in off-pump coronary bypass graft procedures**

Agent	Intended Action <sup>5</sup>
Albumin human	Plasma volume expander for emergency treatment of hemorrhage or shock.
Amiodarone	Antiarrhythmic drug for treatment of atrial and ventricular arrhythmias.
Dopamine hydrochloride	Adrenergic hormone that increases blood flow to the renal, mesenteric, cerebral and coronary blood vessels at low doses.
Epinephrine	Adrenergic hormone that maintains blood pressure and cardiac output by keeping airways open.
Milrinone	Cardiotonic agent with vasodilation properties used in treatment for congestive heart failure.
Sodium nitroprusside	Vasodilator used to treat hypertensive crises and heart failure.
Norepinephrine	Adrenergic hormone that increases blood pressure via vasoconstriction.

rior grafts, such as the LAD, or diagonal arteries.

Greater saphenous vein grafts are harvested simultaneously by the surgical assistant while the surgeon opens the sternum and harvests the LIMA and/or RIMA. Often, the vasoview endoscopic vein harvest approach is used to minimize infection and maximize the healing time.

During the procedure the surgical technologist maintains the sterile field and focuses on the surgeon's needs.

Simultaneously, the anesthesia team loads the patient with 250-500 cc of 0.5% albumin to increase blood volume. The anesthesia team then performs a transesophageal echocardiogram to determine the productivity of the heart and to visualize the heart valves to rule out potential complications. Poor heart function or a regurgitant valve can cause an OPCAB to be impossible because the heart needs to have a good squeeze to perfuse the body. If that cannot be done medically or by placing an intra-aortic balloon pump, then OPCAB may not be optimal. A heart that functions poorly in its normal anatomical position will not perform when manipulated for OPCAB.

The team also administers a test load of milrinone, and then starts an intravenous drip at 0.375 mg/kg. Amiodarone is given prophylactically to control any arrhythmias that may occur while manipulating the heart. The team also prepares low-dose epinephrine, norepinephrine, dopamine and nitroprusside to control blood pressure during the surgery. (See Table 1)

It is very important to have an attentive anes-

thesia team during the manipulating and positioning of the heart. Cardiac displacement allows the exposure of posterior, lateral and inferior targets and can be achieved either by the placement of deep pericardial retraction sutures or by the use of a rummel tourniquet and suture into the oblique sinus.

Exposure of the LAD artery and its diagonal branches—or the proximal right coronary artery (RCA)—can be achieved with minimal displacement by placing laparotomy sponges in the pericardial sac behind the heart and/or temporary retraction sutures.

Many techniques can be used to expose the circumflex artery and its branches, the posterior descending artery, and the posterolateral branch of the right coronary artery. A combination of maneuvers and techniques, including trendelenburg position, placement of lap pads, slings, and pericardial sutures can all be used in conjunction with the use of the suction device.

This device is typically placed near the apex of the heart with suction initiated at approximately 350 mmHg to ensure the heart is held securely. The heart is then displaced and elevated anteriorly, which provides adequate exposure to the vessels on the inferior wall of the heart.

At this point, the anesthesia team administers heparin, typically between 10,000 and 15,000 units (usually half of the dose needed for cardiopulmonary bypass), depending upon the patient's size in order to achieve an optimal ACT (activated clotting time) above 350 seconds.

**Figure 6**  
HEARTSTRING® II  
Proximal Seal  
System



Figures 4, 5, and 6 courtesy of MAQUET® Cardiovascular LLC.

Once the target vessel has been marked as a definite target, the heart has been manipulated, and cardiac stability is assured, the retractor tapes are passed around the target vessels proximally and distally to occlude coronary blood flow.

During the learning process, it is important to leave the vessel occluded for approximately two minutes to check the status of the heart in the manipulated position with the vessel occluded. This interval provides time to prepare the conduit being used for the bypass.

Once stability is confirmed, the U-shaped footplate is positioned over the epicardium, and suction is initiated at 250 mmHg to isolate the target and stabilize the working area of the heart.

The target vessel is then opened using a #69 Beaver blade and extended using angled coronary scissors. The conduit is sewn to the target using a running nonabsorbable polypropylene suture. The suture is then tied and cut.

A 30-cc syringe of warm lactated Ringers solution is used to pressurize the saphenous vein grafts through the vein cannula. The LIMA and/or RIMA are checked by releasing the bulldog clamp on the conduit, which pressurizes the target vessel.

Once all the targeted distal vessels have been bypassed, the saphenous vein graft(s) must be connected to the aorta. To reduce the risk of

emboli release associated with the surgery, side-biting clamps may be used.

The site for the proximal anastomosis is selected and should be free of aortic calcification. In the event calcifications are present, it is imperative that the aorta remain unclamped. This is achieved by using a Derra partial occluding clamp or a nonoccluding clamp, such as the HEARTSTRING® II device (Figure 6).

The proximal site is established by using a #11 blade to stab the aorta, creating a large enough incision to allow the aortic punch to pass through the incision. The proximal hole is punched, and the vein graft is sewn to the aorta using a running nonabsorbable polypropylene suture. If the aorta is calcified and a partial or nonoccluding clamp is needed, it should be deployed after the aorta is punched.

Extra focus on blood loss should occur at this time because an open hole in the aorta can cause the surgical field to quickly become flooded. We have found it is best to punch the hole in the aorta and promptly cover it with a fingertip, then deploy the Heartstring by engaging the plunger, then pulling back on the device. The Heartstring is an umbrella-shaped device which has a suture and a V-shaped wire attached, which creates counter traction for the device to pull upward on the internal wall of the aorta. This creates a bloodless opening to attach the saphenous vein.

Once in place, the proximal site is closed with a running nonabsorbable polypropylene suture, and the nonoccluding clamp is removed according to the manufacturer's directions.

Next, the vein grafts should be de-aired by using a 30-gauge needle to create small holes that allow air to escape rather than entering the coronary arteries.

Now that the bypasses are successfully completed, a low dose of protamine is administered to reverse the effects of heparin, and the surgical wound is examined for bleeding.

Chest tubes are inserted into the pleural and mediastinal spaces to drain postoperative blood and prevent cardiac tamponade. Temporary pacing leads are placed and pass through the myocardium of the left ventricle and/or right atrium.

Then they are passed through the skin in the subxyphoid region and connected to an external pacemaker, if necessary to manage bradycardia.

The sternum is then reapproximated using #7 sternal wires (Figure 7). The fascia and subcutaneous tissues are closed using a vertical mattress absorbable suture, and then the skin is closed with a horizontal mattress absorbable suture.

#### POSTOPERATIVE CARE

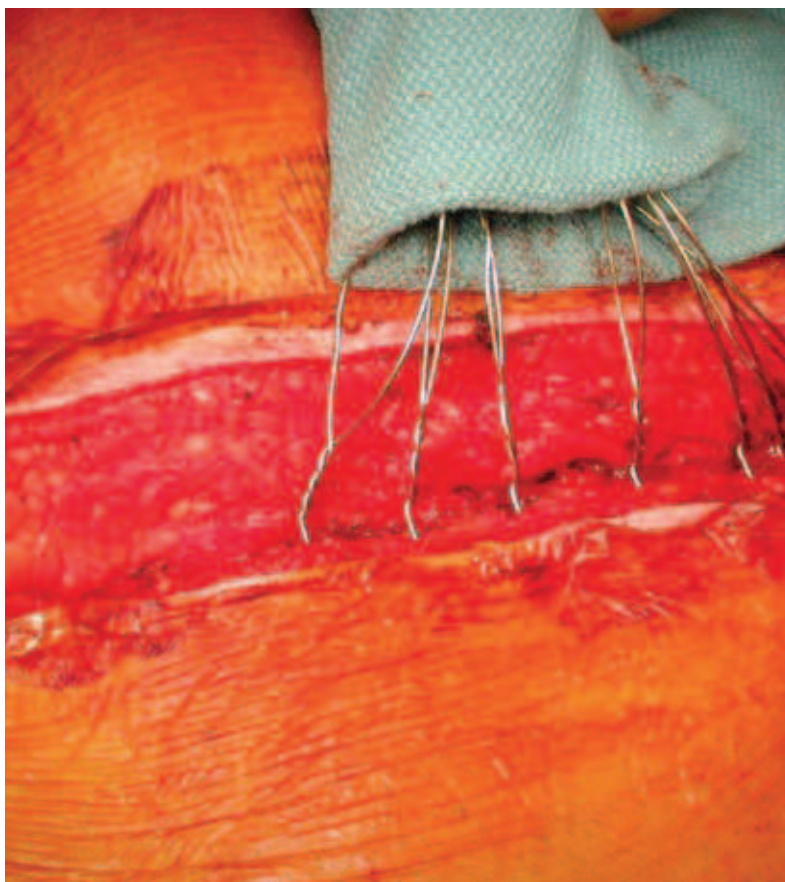
Controlling postoperative pain is a primary factor to consider in expediting a patient's discharge from the hospital. To facilitate postoperative pain management, the ON-Q PainBuster<sup>®</sup> system and catheters are used at this author's facility.

This system delivers a controlled volume of analgesic medicine through two small catheters. Placement of the catheters is critical for pain management. We use a tunneling technique and place the catheters anterior to the rib cage in a subpectoral fashion to block the intercostal nerves.

The postoperative course for OPCAB patients generally consists of monitoring vital signs and chest tube output, management of cardiac output and pressure, checking wounds, and analyzing lab results and making appropriate adjustments.

The OPCAB patient generally can be extubated from the ventilator much sooner which allows for quicker ambulation—a factor in expediting the patient's discharge from the hospital. As stated previously, discharge to home following off-pump CABG can take place two to four days sooner than is typical for conventional CABG patients. Work and social activities may be resumed sooner than the two to three months usually required following conventional bypass grafting.

The postoperative course for any CABG patient can present with complications, such as bleeding, arrhythmias and cardiac arrest. However, the OPCAB patient benefits by not having the many possible complications that CPB can cause with blood factors, and arrhythmias can generally be regulated with intravenous medication, the use of a temporary pacemaker and, if necessary, cardioversion.



Courtesy of Vesiluis.com

**Figure 7**

The sternum was reapproximated with #7 sternal wires.

#### CONCLUSION

In this new millennium, a broad spectrum of myocardial revascularization procedures are available for the treatment of coronary artery disease. The most invasive approach—conventional CABG via full sternotomy—is now being challenged by full and minimally invasive off-pump CABG.

Recent studies, including evidence from randomized controlled trials have shown that although OPCAB may be a new challenge for many surgeons, patients ultimately benefit by recovering more rapidly, requiring less exposure to blood transfusion, and leaving the hospital sooner with quicker rehabilitation.

#### ABOUT THE AUTHOR

Todd W Boice, CST, CFA, currently works at University Cardiothoracic Surgical Associates in Louisville, Kentucky. He received his bachelor of science degree in 1997 from Spalding University in Louisville, Kentucky. He graduated from the



**Table 2. Coronary artery bypass grafting—Practical considerations**

Adapted from *Surgical Technology for the Surgical Technologist: A Positive Care Approach*. Thomson Delmar Learning. ©2004

- The following are important points to remember during a coronary artery bypass grafting procedure. The points that apply only to procedures using cardiopulmonary bypass are included as a refresher for those instances in which an off-pump procedure is converted to on-pump.
- Generally, only those surgical technologists who have been properly trained in open-heart surgery are allowed to scrub cardiac procedures.
  - The [surgical technologist] must have good anticipatory skills, and should understand cardiovascular anatomy and physiology, as well as cardiac procedural sequence.
  - The [surgical technologist] should be thinking five steps ahead of the surgeon throughout the procedure, and should pay attention at all times.
  - It is important that the [surgical technologist] understand cardiac dysrhythmias and their relationship to the cardiac procedure, and be able to understand all pressure readings.
  - Room-temperature saline should be used up to the point of aortic cross-clamping; thereafter, cold saline is to be used until the rewarming period. Warm saline should be used after rewarming begins.
  - There should never be water on the back table. It would be too easy to accidentally use water instead of saline when filling the cannulae. Water will cause lysing of RBCs.
  - Be ready to go back on the pump at a moment's notice. Do not discard cannulae after removal, and keep cannulation sutures ready after the patient is removed from CPB. Keep wire cutters and sternal retractor sterile until the patient is safely out of the O.R.
  - For repeat cardiac procedures, be prepared to cannulate femorally. The oscillating saw may be used for sternotomy to prevent cutting into ventricular adhesions to the sternal wall.
  - Pass of defibrillation cables at the same time as electrosurgical cords. The surgeon will not want to wait for the defibrillation paddles if they are suddenly needed.
  - Wet the surgeon's hands with saline when tying polypropylene sutures to prevent breaking them.
  - Remind the circulator to turn on the suction to the closed-seal drainage unit as soon as the chest tubes are connected to it. This prevents clots from forming in the chest tubes.
  - Keep your Mayo stand and back tables as neat as possible.
  - Check polypropylene sutures for knots or kinks before passing to the surgeon. If one is found, do not try to untie it. Load another as quickly as possible.
  - Laying a light-colored paper towel over the Mayo stand during anastomoses helps make the polypropylene sutures visible.
  - Watch polypropylene sutures for dragging when passing them to the surgeon. They can be easily snagged on items between the Mayo stand and the surgeon. Keep tension off the suture as well.
  - Keep the field clear of instruments, blood-soaked sponges, etc. Wring out blood from laparotomy sponges into a bowl and suction with the pump sucker.
  - Do not confuse the terms "atrial" and "arterial" when passing cannulation stitches. One is for the right atrium, and the other is for the aorta. Typically, the arterial cannulation stitch is placed first, but if aortic pressure is high, the right atrium will be cannulated first.

US Navy's Operating Room Technician School in 1991 and Hospital Corpsmen School in 1987.

#### ACKNOWLEDGEMENTS

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