

# Hybrid Coronary Revascularization (HCR)

Bob Kiaii, MD, FRCS, FACS  
Patrick Teefy, MD, FRCS  
Kumar Sridhar, MD, FRCS  
Michael Chu, MD, FRCS



## **Bob Kiaii, BSc, MD, FRCSC, FACS | London, Ontario**

Dr. Bob Kiaii is Associate Professor, Department of Surgery and Chief and Chair of the Division of Cardiac Surgery at Western University and Director of the Minimally Invasive Robotic Cardiac Surgery Program at the London Health Sciences Centre (LHSC). He is one of the founding members of Canadian Surgical Advanced Technology and Robotics (CSTAR) of the Lawson Health Research Institute. Dr. Kiaii's expertise in robotic cardiac surgery has allowed him to collaborate with Engineers at Western, Cardiologists at LHSC, and Scientists at the Robarts Research Institute, allowing him to receive numerous grants, including a CFI New Opportunities Fund grant. He is a nationally and internationally renowned minimally invasive robotic Cardiac Surgeon. Dr. Kiaii has performed numerous Canadian, North American, and world's "first" cardiac procedures using robotic assistance. He has most recently received the Ray and Margaret Elliott Chair in Surgical Innovation. His bibliography includes a book chapter, eighty-four peer-reviewed papers, sixty-nine published abstracts and more than 162 guest lectures.

## **Patrick Teefy, MD, FRCSC | London, Ontario**

Dr. Patrick Teefy is the Director of the Cardiac Catheterization Laboratories and an Associate Professor at Western University – Department of Medicine and University Hospital, London Health Sciences Centre. Dr. Teefy completed his medical training at the Universities of Ottawa and Toronto and his interventional fellowship at the University of Calgary. In 2002, Dr. Teefy was awarded an Honorary Doctorate by The Council of the Belarusian State Medical University for his humanitarian and scientific activities. Dr. Teefy has a number of publications in peer-reviewed journals specific to the novel approaches to hybrid coronary revascularization. His research interests include stenting and intravascular interventions as well as coronary blood flow utilizing Doppler flow-wire and transcatheter aortic valve implantation.

## **Kumar Sridhar, MD, FRCSC | London, Ontario**

Dr. Kumar Sridhar is an Associate Professor at Western University – Department of Medicine and University Hospital and Interventional Cardiologist and Director of CCU at London Health Sciences Centre. Dr. Sridhar completed his medical training at Western University, London, Ontario and his interventional cardiology fellowship at Western University and Thomas Jefferson University Hospital in Philadelphia, Pennsylvania. Dr. Sridhar has a number of publications in peer-reviewed journals, book chapters and research interests specific to novel treatment coronary interventions and treatment strategies.

## **Michael Chu, MD, FRCSC | London, Ontario**

Dr. Michael Chu is a Cardiac Surgeon and Assistant Professor of Surgery at Western University and London Health Sciences Centre. His clinical practice focuses on minimally invasive and robotic hybrid coronary revascularization procedures, valve reconstruction, transcatheter valve technology and complex aortic reconstruction. He has extensive experience with simultaneous hybrid coronary revascularization procedures, complex mitral and tricuspid valve repair and minimally invasive reoperative mitral valve surgery. He is an active researcher and has investigated different valve reconstruction techniques, minimally invasive and robotic mitral surgery, blood conservation strategies and most recently, experimental transcatheter technology.

Cover Photograph: (left to right) Dr. Bob Kiaii,  
Dr. Patrick Teefy, Dr. Kumar Sridhar, Dr. Michael Chu

# TABLE OF CONTENTS

Hybrid Coronary Revascularization Procedure (HCR) Definition .....	4
Timing and Staging of MICS CABG and PCI .....	4
– Staged MICS CABG Before PCI .....	4
– Staged PCI Before MICS CABG .....	4
– Simultaneous .....	4
Procedural Steps for Simultaneous Approach .....	5
Benefits of the Hybrid OR for HCR .....	5
Patient Selection Considerations for HCR .....	5
– Inclusion criteria .....	5
– Good candidates .....	5
– Contraindications .....	5
Pre-and-Post-op Anticoagulation Considerations .....	6
– Staged .....	6
– Simultaneous .....	6
MICS CABG Surgical Technique .....	7
– LIMA Harvest – direct or robotic .....	7
– Direct vision anastomosis through a small incision .....	7
Anesthesia Considerations .....	9
Perfusion Considerations .....	9
Post-Op Considerations .....	10
HCR Instrumentation .....	10
Discharge and Follow-Up Recommendations .....	10
HCR Clinical Resources .....	11

*This Technique Guide was made possible by a grant from Medtronic, Inc.*



## Important Safety Information

Not all patients are candidates for beating heart procedures. Some patients may require cardiopulmonary support during surgery.

## What is Hybrid Coronary Revascularization (HCR)?

HCR is a revascularization strategy that combines the best advances of Cardiac Surgery and Cardiology. HCR can be defined as minimally invasive left internal thoracic artery to left anterior descending coronary artery bypass graft LITA-LAD (MICS CABG or robotic) with percutaneous coronary intervention (PCI) of the non-LAD territories.

- HCR combines durability of coronary artery bypass surgery (CABG with LITA) to the critical LAD territory with the durability and minimal invasiveness of PCI to non-LAD targets
- HCR is typically performed with a minimally invasive off-pump approach to the LITA-LAD, using a sternal-sparing incision to avoid aortic manipulation and CPB
- Surgical options for LITA-LAD in HCR include direct vision techniques via limited anterolateral thoracotomy, thoracoscopic or robotic-assisted approaches

## PROCEDURE STRATEGY – Timing and Staging: Three Options

### 1. Staged MICS CABG Before PCI

Performing PCI as a separate procedure following CABG allows for optimal antiplatelet therapy plus imaging of the LITA-LAD graft. PCI of high-risk targets is possible if patent LITA-LAD is demonstrated

- Staging may be a day to weeks apart

#### Advantages

- Can avoid bleeding issues with antiplatelet therapy seen with combined CABG/ PCI

#### Disadvantages

- Conventional CABG fallback is complicated if the PCI result is sub-optimal

### 2. Staged PCI Before MICS CABG

Performing PCI before surgery is infrequently performed:

- Post-primary PCI (STEMI) of non-LAD vessel with residual LAD disease is best treated with LITA insertion
- Staging is best delayed a minimum of 6 months

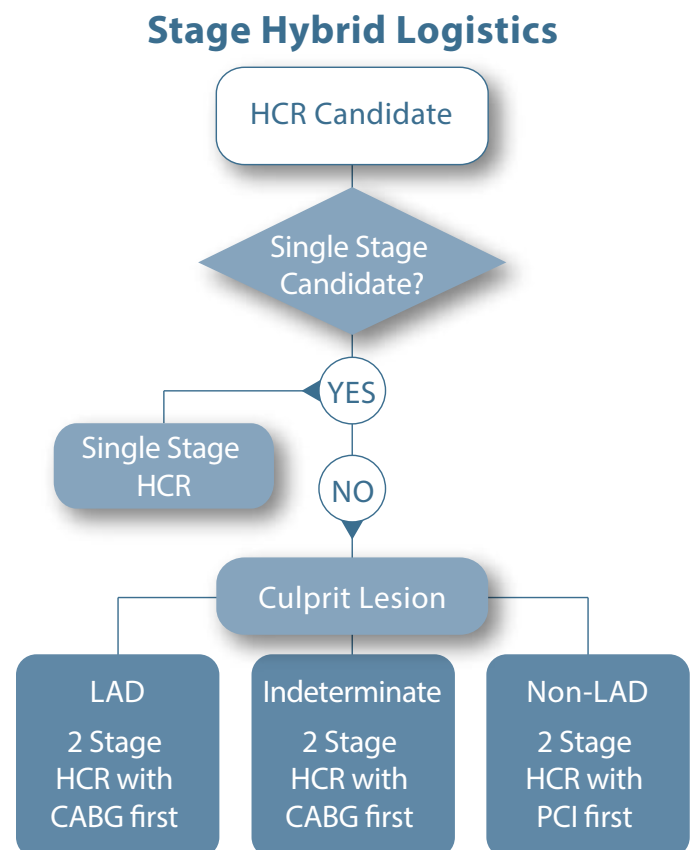
(preferably 12 months) in order to avoid risk of drug-eluting stent thrombosis when clopidogrel is stopped prematurely for 3 to 5 days. Judicious interruption of clopidogrel also minimizes risk of bleeding during CABG. This may be however, a long time to wait in some instances

- Earlier CABG after PCI requires either use of bare metal stent (higher risk restenosis, but less risk thrombosis with stopping clopidogrel after 4-6 weeks) or accepting higher perioperative bleeding risk if dual antiplatelet therapy is continued ( i.e. recent drug-eluting stent implantation)

### 3. Single Stage

Provides patient with a complete one-stop revascularization, allowing immediate completion arteriogram of the LITA-LAD graft

- Utilizes a Hybrid OR setting
- Complete revascularization in same setting
- Increased patient convenience
- Patient subjectively will feel disease is completely treated
- Logistical issues involving increased OR time and challenging multi-specialty collaboration
- Reduces risk of inter-stage morbidities



## Procedural Steps for Single Stage Approach

- MICS CABG procedure first
- Reset room to cardiac catheterization configuration
- LITA graft check
- Confirm hemostasis
- Clopidogrel 600-mg via nasogastric (NG) tube
- Bivalirudin utilized for anticoagulation for surgery and PCI
- PCI performed to non-LAD targets



## A New Standard: Considerations for Adapting a Hybrid OR for HCR

The fields of interventional cardiology and cardiovascular surgery are converging and moving more towards minimally invasive procedures. Hybrid ORs are becoming a standard part of cardiovascular programs and offer the potential to transform how an institute's cardiac care is managed and delivered. HCR in a hybrid OR combines different modalities of treatment into a team approach. There are benefits to building this approach and it's entirely dependent on the people and resources available to implement a facility and assemble the right teams.

### Potential Benefits of a Hybrid OR for HCR:

- Allows for a single stage HCR procedure
- Enables Cardiac Surgeons, Interventional Cardiologists, Anesthesiologists, Nursing and Perfusionists to work simultaneously on one table, in one room and uses a team approach

- Includes a percutaneous catheter-based approach
- Allows for immediate evaluation of the treatment via completion angiogram
- Optimizes surgical/interventional results with reduced trauma in a parallel setup

## Patient Selection Consideration for HCR

### Inclusion criteria

- Young patients, OR
- Age > 70 with comorbidities
- Prior CVA
- Calcified aorta
- Renal dysfunction
- Diabetes
- PVD (may be performed via radial artery)
- Disabled or deconditioned patients
- Patients at high-risk for conventional surgery

### Good candidates for HCR

- Ostial, complex or occluded LAD lesion with simple lesions of other coronary arteries
- Elderly patients, Left Main disease with low Syntax score
- Overweight or diabetic patients
- Comorbidities making sternotomy high-risk
- Younger patients; life expectancy > 10 years and who are not complete PCI candidates
- Patients requiring redo revascularization for multivessel disease and the LITA is not utilized for the LAD

## Contraindications to HCR (especially simultaneous procedure)

### Contraindications to MICS CABG off-pump bypass

- LAD is non-graftable
- LAD is buried or intra-myocardial
- Inability to undergo off-pump beating heart revascularization
- Previous surgery involving left chest cavity
- Left subclavian artery stenosis rendering the LITA unsuitable
- Lack of tolerance of single lung ventilation based on FEV1 < 50% FVC

## Contraindications to PCI of non-LAD lesions

- Peripheral vascular disease precluding vascular access - consider radial artery access
- Vessel size < 2.5-mm
- Tortuous calcified vessels felt to preclude stent placement
- Complex disease requiring prolonged procedure time (esp. simultaneous HCR)
- High SYNTAX scores of PCI vessel especially if surgery is a better option
- Fresh thrombotic lesions
- Renal insufficiency
- Contraindication to dual antiplatelet therapy

## Other potential contraindications

- Cardiogenic shock
- Malignant arrhythmias
- Hemodynamically unstable
- History of chronic lung disease
- Morbid obesity

## Anticoagulation/Antiplatelet Considerations

### Staged – MICS CABG 1st

- Heparin with protamine reversal
- Start clopidogrel after CABG – either next day or prior to the PCI (600-mg more than 6 hours prior to PCI)

### Staged – PCI 1st

- The usual anticoagulation and antiplatelet for PCI
- Holding of clopidogrel (but continue ASA) for 3-5 days prior to MICS CABG depends on timing and type of stent (DES vs BMS)

### Single Stage – Simultaneous HCR (see Figure 1.0)

- ASA pre-procedure
- Prior to ligation of the LITA, give 0.75-mg/kg bolus of bivalirudin, then an infusion of 1.75-mg/kg/hr is maintained throughout the surgery and PCI procedure to keep ACT > 300 seconds
- Once the LITA-LAD patency is confirmed, 600-mg clopidogrel is given via NG tube (provided chest tube drainage is minimal)

## Single Stage Anticoagulation/Antiplatelet Consideration

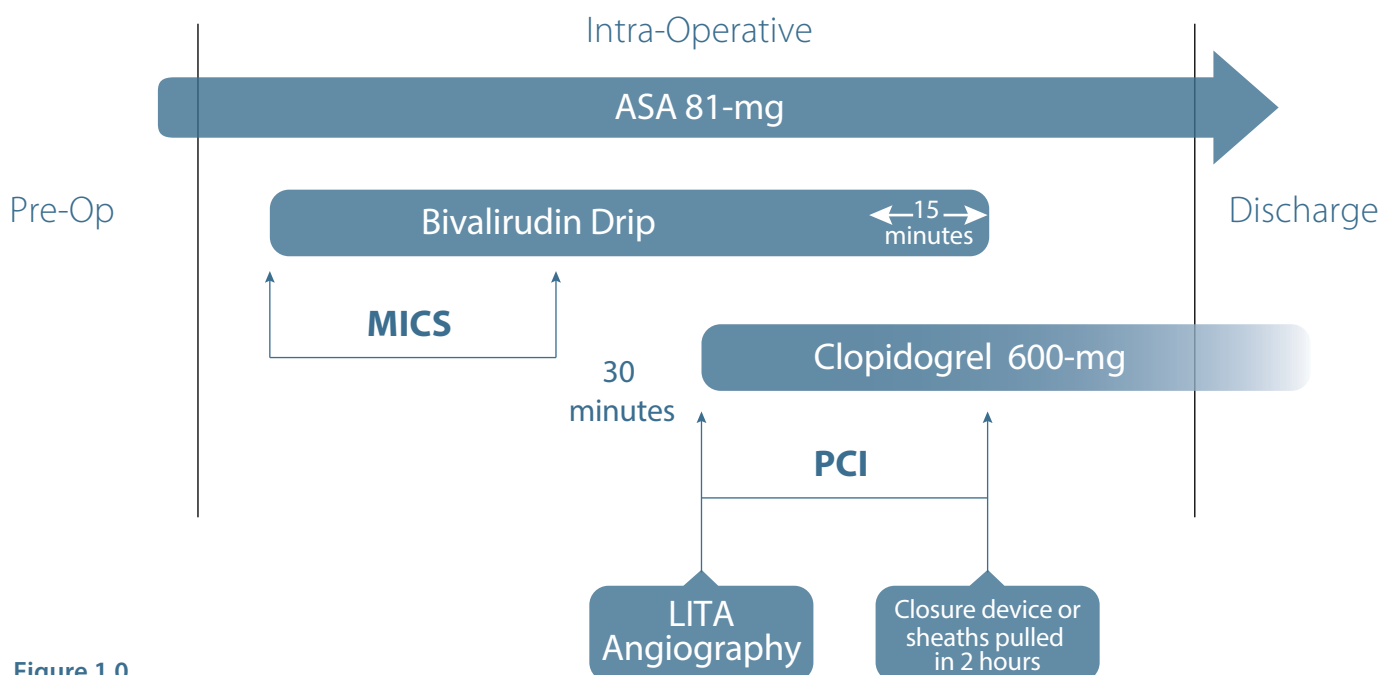


Figure 1.0

- PCI performed in hybrid OR
- After 2 hours, bivalirudin is discontinued
- Patients receive an additional 81-mg of ASA, 6 hours following the procedure
- Patients are started on clopidogrel 75-mg daily, starting the day following the procedure

## MICS CABG SURGICAL TECHNIQUES

### I. Direct ITA Harvest

#### 1. Patient Set-up

- Lines/Airway – Double lumen ETT with internal jugular central line
- Positioning is 30 degrees right lateral decubitus with a roll under left shoulder

#### 2. Thoracotomy/Incisions

Perform a 5 to 7-cm anterolateral mini-thoracotomy

- Male patients: over the 5th or 6th ICS, 1/3 medial to the nipple
- Female patients: inframammary incision similar location
- The medial 2/3 of the window incision is medial to the anterior axillary line
- While making the incision, deflate the left lung
- Divide the intercostal muscles laterally to reduce the risk of rib fracture, then divide them medially to avoid damage to the LITA
- A soft tissue retractor may be placed in the incision to maximize access

### 3. Direct ITA Harvest

- Place a large Kelly clamp with a sponge in the 6th ICS to assist with harvesting the LIMA. Use the sponge to push away tissue for better IMA visualization
- Insert the ThoraTrak™ MICS retractor system into the ICS incision; then hook the ThoraTrak MICS retractor system to the Rultract® to facilitate the LIMA harvest
- In order to prevent crush injury to the LIMA, make sure the superior portion of the retractor is placed and maintained in the lateral aspect of the incision
- Care should be taken not to fracture a rib
- The ThoraTrak MICS retractor system should be cranked slowly, which allows tissue and bone to acclimate to the change in position in order to minimize the potential for rib fracture and pain
- Start the LIMA harvest at the 3rd ICS using direct vision through the window incision
- Use an extended electrocautery instrument, endoscopic forceps, suction, endoscopic clip applier and small clips for the harvest
- Complete the harvest up to the subclavian vein and down past the left 5th ICS
- Take care to identify and avoid the phrenic nerve
- During the LIMA harvest, flexing the table may facilitate access to the superior portion of the LIMA
- Anchor the pedicle of the LIMA with silk ties to maintain the proper orientation
- Give intravenous bivalirudin or heparin prior to LIMA division



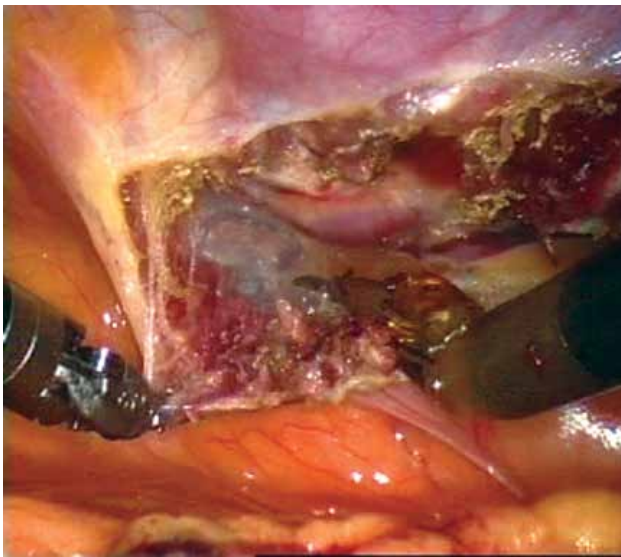
## II. Endoscopic/Robotic Harvesting of the LITA and/or RITA

### 1. Patient Set-up

- Positioning is 30 degrees right lateral decubitus with a roll under left chest to allow shoulders to fall

### 2. Endoscopic Port Insertion

- The left lung is deflated and in the 5th ICS 12-mm port inserted
- CO<sub>2</sub> insufflation for intrathoracic pressure 5 to 10-mmHg (watch blood pressure)
- 30 degree endoscope inserted. Under the guidance of the endoscope, quantity of two 7-mm ports, inserted in the 3rd and 7th ICS
- Endoscopically or robotically the LITA is harvested from 1st rib to the 6th rib
- Endoscopically the pericardium is opened and the location of the LAD identified and using a spinal needle the location for the thoracotomy is selected to provide the best access to the LAD
- Prior to ligation of the LAD, patient is given intravenous bivalirudin or heparin depending on 1 stage or 2 stage procedure



### 3. LITA-LAD Anastomosis (Applies to Direct and Robotic Harvest Techniques)

- The LITA-LAD anastomosis is performed under direct vision through the mini-thoracotomy
- Only soft tissue retraction is generally required, minimizing trauma
- Open the pericardium down to the diaphragm and towards the right pleura
- With the LITA visible through the incision, place the Octopus™ Nuvo Tissue Stabilizer through the 6th ICS if LITA directly harvested or 5th ICS if LITA is endoscopically harvested and stabilize the LAD using suction
- Once stabilized, the LAD is occluded and the bypass is grafted using standard instruments
- In some instances, it may be necessary to use a Starfish™ NS Heart Positioner placed through a sub-xiphoid portal in order to position the anastomotic site in the thoracotomy window



Octopus Nuvo  
Tissue Stabilizer



## Anesthesia Considerations

- An intrathecal block with epimorphine is used for pain control
- Defibrillator pads on the left scapula and inferior and medial to the right breast
- Perform intubation with a double lumen endotracheal tube to deflate the left lung. Alternatively, a single lumen endotracheal tube (ETT) and bronchial blocker may be placed under fiber-optic guidance
- Lines are routine and include an arterial line and PA catheter (PAC). If peripheral access is limited, at least a 16-gauge IV should be placed. A triple lumen catheter is placed along with the PAC – “double stick”
- After intubation, place a bronchial blocker into the mainstream bronchus with fiberoptic guidance. Place the proximal end of the balloon approximately 1 to 2-cm below the carina
- Warming blanket should be used to avoid hypothermia
- CO<sub>2</sub> insufflation for intrathoracic pressure 5 to 10-mmHg (watch blood pressure)
- Hemodynamic support for OPCAB surgery is necessary

## Single-Lung Ventilation

- Deliver approximately 10 cc/kg of tidal volume prior to and during single-lung ventilation. Tidal volume may need to be decreased as large tidal volumes can cause shifting of the mediastinum, which may cause the MICS retractor to slip
- Keep the O<sub>2</sub> saturation greater than 90%. If the saturation begins to decrease:
  - Add continuous positive airway pressure (CPAP) of 5-cm H<sub>2</sub>O to the deflated lung. This can be performed through the bronchial blocker by inserting a 7 ETT connector into the barrel of a 3-cc syringe. Insert the syringe tip into the lumen of the bronchial blocker. Attach the 7 ETT connector to a CPAP circuit
  - CPAP can be increased, but if it is increased too much, it will cause the lung to inflate and obscure the surgeon’s view

## Perfusion Considerations

The need for extracorporeal support is rare.

A supported coronary revascularization would only require a system with a venous reservoir, arterial pump, oxygenator and filter. It is recommended that the extracorporeal support system and devices be on standby.

- The use of a cell saver is recommended
- Percutaneous cannulae are necessary if femoral cannulation is utilized for hemodynamic support

## Post-Op Considerations

### Discharge and Follow-Up Recommendation

- Discharge once stable between 2 to 4 days
- Clopidogrel, aspirin, and other cardiac medications as indicated at discharge
- Clear instructions on the importance of dual antiplatelet therapy; call office if there is a need to change
- Follow up in 6 weeks
- Follow up in 6 months, consider angiography to assess patency of the graft/stent
- Annual follow-up

### HCR Surgical Instruments and Disposable Surgical Instruments

- ThoraTrak™ MICS Retractor System
- Rultract® Skyhook Surgical Retractor System™
- Bedrail mounted instrument holder

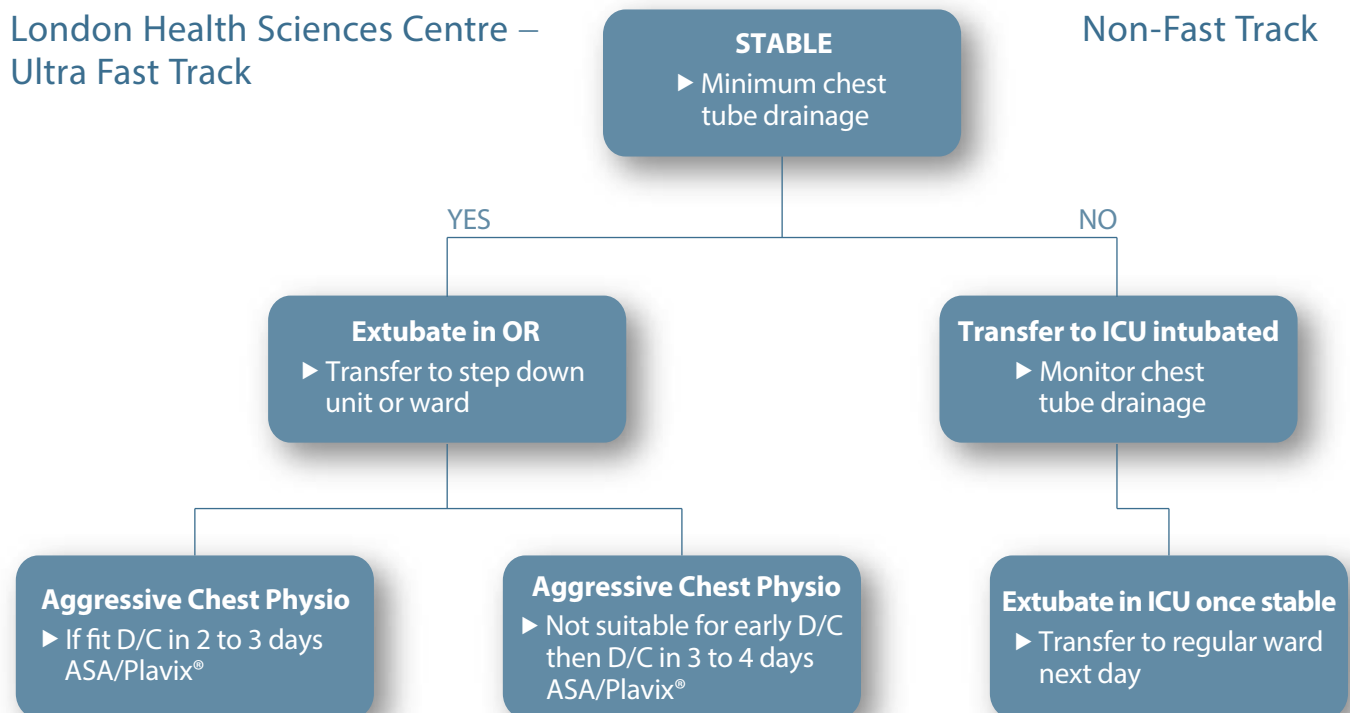
### Single-shafted instruments:

- Chest tube passer
- Curved scissors
- Curved mini needle holder
- Mini potts scissors: 45° and 125°
- DeBakey mini grasper
- Mini (ITS) holding forceps
- Clip applying forceps, small and medium sizes

### Disposables

- Octopus™ Nuvo Tissue Stabilizer
- Starfish™ NS Heart Positioner (if needed)
- Bio-Medicus™ Percutaneous Cannulae Kit
- Disposables for Robotic ITA Take-Down (if Robotic ITA harvest)

## London Health Sciences Centre – Ultra Fast Track



## HCR Clinical Resources

- Adams C, Burns DJ, Chu MW, et al. Single-stage hybrid coronary revascularization with long-term follow-up. *Eur J Cardiothorac Surg*. 2013 Aug 15. doi:10.1093/ejcts/ezt390
- Bonatti J, Lehr E, Vesely MR, Friedrich G, Bonaros N, Zimrin D. Hybrid coronary revascularization: which patients? When? How? *Curr Opin Cardiol*. 2010;25:568-574.
- DeRose JJ. Current State of Integrated "Hybrid" Coronary Revascularization. *Sem Thorac Cardiovasc Surg*. 2009;21:229-236.
- Desai ND, Cohen EA, Naylor CD, et al. A randomized comparison of radial-artery and saphenous-vein coronary bypass grafts. *N Engl J Med*. 2004;351:2302-2309.
- Halkos ME, Rab ST, Vassiliades TA, et al. Hybrid coronary revascularization versus off-pump coronary artery bypass for the treatment of left main coronary stenosis. *Ann Thorac Surg*. 2011;92:2155-2160.
- Hoff SJ, Ball SK, Leacche M, et al. Results of completion arteriography after minimally invasive off-pump artery bypass. *Ann Thorac Surg*. 2011;91:31-36.
- Kiaii B, McClure S, Stewart P, et al. Simultaneous integrated coronary artery revascularization with long-term angiographic follow-up. *J Thorac Cardiovasc Surg*. 2008;136:702-708.
- Kon ZN, Brown EN, Tran R, et al. Simultaneous hybrid coronary revascularization reduces postoperative morbidity compared with results from conventional off-pump coronary artery bypass. *J Thorac Cardiovasc Surg*. 2008;135:367-375.
- Lapierre H, Chan V, Sohmer B, Mesana TG, Ruel M. Minimally invasive coronary artery bypass grafting via a small thoracotomy versus off-pump: a case-matched study. *Eur J Cardiothorac Surg*. 2011;40:804-810.
- Lee SW, Park SW, Kim HK, et al. A randomized comparison of sirolimus versus Paclitaxel-eluting stent implantation in patients with diabetes mellitus. *J Am Coll Cardiol*. 2008;52:727-733.
- Lincoff AM, Bittl JA, Harrington RA, et al. Bivalirudin and provisional glycoprotein IIb/IIIa blockade compared with heparin and planned glycoprotein IIb/IIIa blockade during percutaneous coronary intervention: REPLACE-2 randomized trial. *JAMA*. 2003;289:853-863
- McGinn JT Jr., Usman S, Lapierre H, Pothula VR, Mesana TG, Ruel M. Minimally invasive coronary artery bypass grafting: dual-center experience in 450 consecutive patients. *Circulation*. 2009;120:S78-S84.
- Merry AF, Raudkivi PJ, Middleton NG, et al. Bivalirudin versus heparin and protamine in off-pump coronary artery bypass surgery. *Ann Thorac Surg*. 2004;77:925-931.
- Nollert G, Wich S. Planning a cardiovascular hybrid operating room: the technical point of view. *Heart Surg Forum*. 2009;12:E125-E130.
- Popma JJ, Nathan S, Hagberg RC, Khabbaz KR. *Cath Cardiovasc Interv*. 2010;25:S28-34.
- Poston RS, Tran R, Collins M, et al. Comparison of economic and patient outcomes with minimally invasive versus traditional off-pump coronary artery bypass grafting techniques. *Ann Surg*. 2008;248:638-646.
- Repossini A, Tespili M, Saino A, et al. Hybrid Revascularization in multivessel coronary artery disease. *Eur J Cardiothorac Surg*. 2013;44:288-293.
- Serruys PW, Morice MC, Kappetein AP, et al. Percutaneous coronary intervention versus coronary-artery bypass grafting for severe coronary artery disease. *N Engl J Med*. 2009;360:961-972.
- Sutter FP, Berry T, Wertan MC. Precision incision: robotic coronary revascularization via 3.9-cm minithoracotomy. *Innovations (Phila)*. 2012;7:223-228.
- Vassiliades TA Jr., Douglas JS, Morris DC, et al. Integrated coronary revascularization with drug-eluting stents: immediate and seven-month outcome. *J Thorac Cardiovasc Surg*. 2006;131:956-962.
- Yun KL, Wu Y, Aharonian V, et al. Randomized trial of endoscopic versus open vein harvest for coronary artery bypass grafting: six-month patency rates. *J Thorac Cardiovasc Surg*. 2005;129:496-503.
- Zhao DX, Leacche M, Balageur JM, et al. Routine intraoperative completion angiography after coronary artery bypass grafting and 1-stop hybrid revascularization results from a fully integrated hybrid catheterization laboratory/operating room. *J Am Coll Cardiol*. 2009;53:232-241.

### **Bio-Medicus™ Femoral Cannulae**

Care and caution should be taken to avoid damage to vessels and cardiac tissue during cannulation or other cardiac surgery procedures. For a listing of indications, contraindications, precautions and warnings, please refer to the Instructions for Use. **Caution:** Federal law (USA) restricts this device to sale by or on the order of a physician.

### **Octopus™ Nuvo Tissue Stabilizer**

#### **Starfish™ NS Heart Positioner**

#### **ThoraTrak™ MICS Retractor System**

**Important Safety Information:** Not all patients are candidates for beating heart procedures. Some patients would require pulmonary support during surgery. See *Instructions for Use* for a complete list of warnings, precautions and contraindications. **Caution:** Federal law (USA) restricts this device to sale by or on the order of a physician.