Tips and Pitfalls in Off-pump Coronary Artery Bypass

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Off-pump coronary artery bypass grafting (OPCAB) has emerged as an alternative to the traditional on-pump approach. It is particularly beneficial in high risk patients with aortic pathology and low ejection fraction. Off-pump surgery needs a committed surgeon, a cooperative team, and a standardized technique to be consistently successful. Communication is the cornerstone of OPCAB surgery.

GENERAL INTRAOPERATIVE CONSIDERATIONS

- Standard monitoring: electrocardiogram (EKG), arterial line, Swan–Ganz catheter, cerebral oxymetry, transesophageal echocardiography (TEE), and Foley catheter.
- Temperature monitoring: Systemic hypothermia < 34°C - associated with bleeding and arrhythmias. -> maintain normothermia

ANTIPLATELET AND ANTICOAGULATION MANAGEMENT

- All patients are maintained on aspirin through surgery. Clopidogrel is continued only in patients who have drug eluting stents or are at an increased risk of stroke.
- Full heparinization and an activated clotting time (ACT) goal of >300 seconds.
- Postoperatively, aspirin and clopidogrel are administered 6 hours after surgery if bleeding is controlled.

OPERATIVE TECHNIQUES

Conduits

- Internal mammary artery: pedicled or skeletonized / papaverin injection – intraluminal/perivascular
- Saphenous vein: thigh or calf / pedicled
- Radial artery: harmonic scalpel. Should be soaked in solution with Ca-channel blockade and heparin.

Exposure of Coronary Vessels

- The sternal retractor is positioned at the lower end of the sternum, allowing asymmetric opening of the sternum. Opening the lower end more than the upper end of skin incision is advantageous.
- Exposure of LAD: retraction stitches on pericardium: left cut edge of pericardium & wet/dry sponge tape
- Exposure of lateral wall: apex suction device / a deep pericardial stitch between the left pulmonary veins and the inferior vena cava.
  Right pleurotomy to prevent overcompression of right sided heart during the elevation of apex
  Adequate fluid administration
- Exposure of the right coronary territory: Trendelenburg position

Hemodynamic Management

- Once the heart is rotated into position, the procedure is paused to ensure that hemodynamics are stable. Hemodynamic changes may occur immediately upon cardiac displacement or later during the anastomosis. -> Communication between the anesthesiologist and surgeon.
- Serious instability in which the heart needs to be back in the native position: elevated pulmonary artery pressures (PA), arrhythmias, global hypokinesia, a decrease in systemic blood pressure, and the onset or worsening of mitral regurgitation (MR).
- Displacement is often tolerated better the second time.
- Persistence in the face of instability -> emergent conversion to CPB or end-organ damage and acidosis.
- Patients respond to the apical traction and displacement with worsening MR, increased PA pressures,

and hemodynamic instability -> “deep pericardial stitches”
- CPB support should be elective.

GRAFT CONSTRUCTION

Sequence of Grafting

- LAD first-> rPD -> OM
- Intracoronary shunt for LAD, RCA

Proximal Anastomoses

- Examination of the ascending aorta in high-risk patient (renal failure, prior stroke, peripheral vascular disease, or who are older than 80 years of age) by preoperative CT scan, epiaortic ultrasound
- Grading of aorta: Grade 1 or 2-> partial occlusion clamp (SBP<110mHg)
  Grade 3 or worse-> heart-string device
- No appropriate spot on the ascending aorta: the innominate artery, the right internal mammary artery, or a T graft with the proximal on the left internal mammary artery.
- Assessment of graft flow: transit time ultrasound

Distal Anastomoses

- The vessel is held at zero position with the stabilizer resting lightly but rigidly on the surrounding myocardium. Downward pressure (compression) on the myocardium will often reduce stabilization and increase hemodynamic compromise.
- Interruption of blood flow in the target vessel: encircling Silastic loop proximally.
  Calcified vessel -> intracoronary shunt.
- CO_2 blower
- Stay sutures of 6-0/5-0 monofilament polypropylene.

Collaboration with the anesthetist

- The anesthetist: the important partner during OPCAB. The surgeon must provide the anesthetist detailed information about matters taking place in the operating field.
- The anesthetists’ permission must be obtained before stating coronary artery incision.

POSTOPERATIVE CARE

- Fast-track approach: Extubation within 6 hours.
- Limitation of crystalloid fluids in the postoperative period (d/t hypervolemia during intraoperative period to maintain stability during displacement of the heart)
- Active rewarming
- Controlled transfusion by protocol
- Early ambulation
- Early postoperative beta blockade
- Pain control to allow aggressive respiratory exercises and early ambulation. Patients are weighed daily.
- Diuresis to reach preadmission body weight before discharge.
- Dual antiplatelet therapy for 1 year and cholesterol lowering medications particularly statins.

CONCLUSIONS

The adoption of this technique varies widely. In South Korea, approximately 50% of cases are performed in the off-pump fashion for the revascularization. There is sufficient evidence that the highest risk patients benefit disproportionately from OPCAB. With the use of a standardized technique, careful planning, and good communication, excellent results with a low conversion rate are achieved.

Postoperative care after Cardiac Operation

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- Ill-advised or overly energetic interventions early after operation can put a patient at risk who would otherwise convalesce normally
- Whole body inflammatory response to CPB
- Alertness to deviations from the patterns of an uncomplicated convalescence is mandatory

- Optimal, suboptimal but in control, critically ill
  - Optimal : routine care, no change or important modification is currently necessary or foreseeable
  - Suboptimal but in control : careful consideration is given to a change in therapy, and a new modality is likely(e,g. additional catecholamine support for low CO or lidocaine drip for premature ventricular contraction (PVCs)
  - Critically ill: a modification, change, or new intervention is necessary and urgent(e,g. Tx of oliguria or metabolic acidosis, return to OR for bleeding)

Abnormal convalescence

Cardiovascular subsystem

- Cardiac reserve
  - Capacity to increase CO as a response to a variety of stressful sudden developments
  - Myocardial contractility and coronary blood flow

Cardiovascular system

- Cardiac reserve
  - Inadequacy of cardiac reserve
    - Increased Vo_2 : total body o_2 consumption
      - Struggling or hyperthermia
    - suddenly increased ventricular afterload
    - Acute reduction in ventricular preload

Cardiovascular system

- Adequacy of blood flow : cardiac output
  - Cardiac index
    - at least 2.0 l/min/m^2, 2.2-4.4
    - In young pt, lower after operation, then rise after 9-12 hrs
    - CI and Vo_2 : prognosis !!!

Cardiovascular system

- Adequacy of blood flow : cardiac output
  - Arterial blood pressure
    - SVR usually elevated immediately
      - Circulating catecholamines, plasma renin, angiotensin II
    - SVR down in..children with cyanotic heart disease, adults with DM, sepsis and ACE inhibitors
  - Petal pulse
  - Skin temperature

Cardiovascular system

- Adequacy of blood flow : cardiac output
  - Whole body oxygen consumption
    - Vo2 = Q (Cao2-Cvo2)
    - Normal : 155ml/min at 37´C
    - Reduced : shock
  - Mixed venous oxygen level
    - Mean tissue oxygen level
    - < 30 mmHg, < 23 mmHg

Cardiovascular system

- Adequacy of blood flow : cardiac output
  - Urine flow and serum potassium
    - Hyperkalemia(>5mEq/l) over 4 hrs : sensitive indicator of a low or falling CO in neonates and infants
  - Metabolic acidosis
    - Almost always a result of lactic acidemia
    - Suboptimal CO and oxygen consumption (>5 mEq/min, >10 mEq/min)

Cardiovascular system

- CO and its determinants
  - Ventricular preload
  - Ventricular afterload
  - Mocardial contractility
  - Heart rate

Cardiovascular system

- Preload
  - LVEDV
  - LVEDP – LAP – PCWP
- Afterload
  - Systolic wall stress
    - Ventricular transmural pressure during systole
    - Ventricular wall curvature
    - Ventricular wall thickeness
    - Shape of ventricle

Cardiovascular system

- Afterload increase > 10%
  - ↓ stroke volume
  - ↑ tearing the aortic purse-string suture/suture lines
  - ↑ LV metabolic demands : latent myocardial ischemia
  - The patient's preoperative BP must be taken into account, and to avoid cerebral complications, markedly hypertensive patients must not be rendered hypotensive.

Cardiovascular system

- HR
  - normal compensatory response to ↑ oxygen demand : ↑ HR
  - In eldery, dieseased myocardium : no response

Cardiovascular system

- Cardiac rhythm
  - Junctional rhythm : 10-15% ↓ of CO
  - Bradyarrhythmia : damage to AV node or His bundle, hypoxemia, drug – LCOS
  - Tachyarrhythmia : hypotension

Cardiovascular system

- Low cardiac output
  - Inadequate operation : The surgeon's responsibility for obtanining an adequate operation demands that he or she continue to search for evidence of this postoperatively, particularly when the patient has low cardiac output.

Cardiovascular system

- Low cardiac output
  - Myocardial dysfunction
    - Elevated atrial pressure in the absence of any other explanation
    - TEE, CK-MB, Tro I
  - Reduced preload
    - Hypovolemia : relative volume loss due to vasodilation, bleeding
    - Diastolic dysfunction : LV hypertrophy, fibrosis, myocardial edema
    - Acute cardiac tamponade

Cardiovascular system

- Low cardiac output
  - Increased ventricular afterload
    - RV afterload : neonates and infants
    - LV afterload : sudden ↑ of systemic arterial pressure
      - Suctioning, restlessness, or hypoxia
      - Combined with impared LV reserves → low cardiac output
      - Sustained inc in SVR : half of open heart surgery pt.

Cardiovascular system

- Risk factors for LCO
  - Patient specific
    - Chronic impairment of ventricular preload, afterload, and/or contractility(ventricular hypertrophy, stiffness, chronic heart failure)
  - Procedural
    - Discrepancy between the duration of any global myocardial ischemia and the efficacy of the measures used for myocardial management
    - Extensive whole body inflammatory response

Cardiovascular system

- Risk factors for LCO
  - Incomplete or inadequate operation
  - Acute myocardial ischemia
  - Incomplete relief of ventricular inflow or outflow obstruction
  - Residual or created AR or MR
  - Residual or created VSD or large L to R shunt

Cardiovascular system

- Tx of LCO
  - Early intensive treatment : good recovery
  - Preload : 15-20 mmHg
  - Afterload : vasodilating agent
  - RV dysfunction with long standing MV disease or congenital heart disease : nitroprusside or phentolamine
  - HR : pacing or catecholamine

Cardiovascular system

- Tx of LCO
  - IABP : not responsive to optimized preload, afterload, heart rate or dopa(>10)
    - In OR rather than postop.
    - Severe LV dysfunction w/s myocardial ischemia, pt with myocardial ischemia and inadequate cardiac output or severe ventricular arrhythmia
    - Ischemic heart disease, valvular heart disease, congenital heart disease
    - Begin in a 1:1 and weaning as early as 6-12 hrs after insertion
    - Dopamin less than 5 ug/kg/min

Cardiovascular system

- Tx of LCO
  - Temporary ventricual assistance : VAD
  - Cardiopulmonary support and ECMO

Cardiovascula system

- Tx of LCO
  - Cardiac arrhythmia(postop.1-2 days)
    - Ventricular electrical instability : PVCs, v-tach, v-fib
      - Indication of Tx : ventricular electrical instability > 6/min, 20-30 min even with good cardiac performance
      - Treating ventricular arrhythmia other than ventricular tachycardia is probably no necessary.(CASTrial)
      - V.tachy with EF<40% : early EP study

Cardiovascular system

- Tx of LCO
  - Cardiac arrhythmia(postop.1-2 days)
    - Atrial arrhythmia
      - >20%
      - Prevention : beta blocker(?)
      - Tx : rate control or conversion to sinus rhythm
    - Atrial flutter
      - Rapid atrial pacing, ibutilide
    - Paroxysmal atrial tachycardia
      - JET(junctional ectopic tachycardia) 5-8%, in children, VSD
        - » Sedation, hypothermia to 34'C, procainamide, amiodarone

Pulmonary subsystem

- During intubation
  - Normal P(A-a)o2 < 10 mmHg
  - After OHS : P(A-a)o2 ↑

Pulmonary subsystem

- During intubation
  - Pt's RR : useful guide
  - Pt-triggered respiratory rate : 8-12/min
  - PEEP : 5-8 (older than 12yrs)
    - Larger lung volumes
    - Fewer pefused but nonventilated alveoli
    - Smaller P(A-a)O2 after extubation
    - Relative CIx : COPD, children with Fontan operation or cavopulmonary anastomosis

Pulmonary subsystem

- Extubation
  - Paco2, Pao2, visual estimate work of breathing
  - Cause of dysfunction
    - During CPB
      - Neutorphil activation
      - Throboxane B2 ↑: pulmonary vascular inflammation
      - IL-6, IL-8 : membrane damage and neutrophil activation
      - Alveolar-capillary barrier : more permeable
      - Pulmonary edema

Pulmonary subsystem

- Extubation
  - Cause of dysfunction
    - Early after CPB : permeability ; IV albumin – tracheobronchial tree
    - Postop. Increased PML infiltration – reduction of pulmonary surfactant activity
    - Direct trauma to lung
      - Secretion
      - Phrenic nerve injury
      - LLL atelectasis
      - Localized or more extensive pulmonary edema in elderly
      - Frank pulmonary hemorrhage

Pulmonary subsystem

- Risk factors for acute dysfunction
  - Patient-specific
    - Young age <2 yo
    - Older age > 60 yo
    - COPD : inc work of breathing and air trapping
    - Pulmonary arterial hypertension
    - Amiodarone : pulmonary dysfunction after cardiac surgery

Pulmonary subsystem

- Risk factors for acute dysfunction
  - Procedural
    - Oxygenator other than membrane-type
    - Proper filter in a. tubing : reduce pulmonary damage
    - Duration of CPB – extracellular water : direct correlation
    - Amount of C3a : greater amount of neutrophil infiltration

Pulmonary subsystem

- Risk factors for acute dysfunction
  - Postoperative
    - ↑ LAP, pulmonary capillary and venule pr
    - The longer on a ventilator, the greater the chances of pulmonary dysfunction
    - Phrenic nerve palsy

Pulmonary subsystem

- Course of dysfunction
  - Dysfunction may still be present POD 10 days
    - Normal convalescence, 3-6 days, orthopnea and paroxysmal noctural dyspnea in marked LV hypertrophy or poor LV dysfunction preoperatively with normal chest X ray
  - Lung volume(VC, TLV) decreased
    - Revert to normal within 3-6 months

Pulmonary subsystem

- Management and Tx of dysfunction
  - General measures
    - Extubation
      - in the daytime than at night
      - should be delayed only in pt with assisted device and possibility of early reop. ,within 6 hrs, if possible
      - Stable and satisfactory cardiac performance
      - Lack of important cardiac arrhythmia
      - Appropriate awakening ,satisfactory neurologic status

Pulmonary subsystem

- Management and Tx of dysfunction
  - General measures
    - Paco2 :30-35 mmHg
    - Hemoconcentration
    - Diuretics
    - Difficult to wean
      - Spontaneous breathing trials
      - Decreasing levels of pressure support

Pulmonary subsystem

- Management and Tx of dysfunction
  - Prolonged intubation
    - Criteria for extubation are not met
    - Neurologic complication are present
    - Severe dysfunction of the cardiac subsystem is present
    - Persistent chest drainage or a residual cardiac defect make early return to the OR likely

Pulmonary subsystem

- Management and Tx of dysfunction
  - Prolonged intubation
    - Sedation and NM blockade
    - Agitated pts
      - First priority : evaluation of cardiac and pulmonary subsystem !!
      - Benzodiazepine, opioid analgesics, propofol, haloperidol
    - Pneumothorax
    - Bronchospasm
    - Tracheostomy (> 10days)

Pulmonary subsystem

- Management and Tx of dysfunction
  - Reintubation
    - Paco2 > 50mmHg over 4hrs
    - Signs of decreasing cardiac output
    - Signs of exhaustion from breathing spontaneously
    - Excessive pulmonary secretions with ineffective coughing
    - Reintubation should be performed by a copetent professional

Pulmonary subsystem

- Management and Tx of dysfunction
  - Pulmonary hypertensive crises
    - Irreversible, hyperacute rise in pulmonary arterial pr accompanied by bronchospasm, followed within seconds or accompanied by profound reduction in cardiac output and fall in Sao2

Renal subsystem

- Adequacy
  - Urinary catheter : as least 2 days after operation
  - Serum potassium : every 4 hrs during first 24 hrs
  - Serum creatinine and BUN : daily during first 48 hrs

Renal subsystem

- Adequacy
  - Urine output
    - 500ml/24hrs/m^2, 167ml/8hrs/m^2, 20ml/hr/m^2
    - 0.5-1ml/hr/kg in infants and small children
    - Diuresis phase in early after operation
    - Postop.renal dysfunction(> 2 x serum creatinine)
      - 1% in preop.normal
      - 16-20% in preop.dysfunction

Renal subsystem

- Risk factors for acute dysfunction
  - Patient-specific
    - Preop.impairment of renal Fx
    - Chronic heart failure(preop. NYHA class IV)
    - Cyanotic heart disease
    - Neonates and infants
    - Obesity

Renal subsystem

- Risk factors for acute dysfunction
  - Procedural
    - Long period of CPB
    - Longer duration of hypothermic circulatory arrest
    - CPB priming with whole blood
    - High plasma Hb level(>40 mg/dl) during and early after CPB
  - Postoperative
    - Acute reduction in cardiac output
    - Antibiotics like aminoglycoside

Renal subsystem

- Management and treatment
  - Fluid administration program
    - Avoidance of fluid overload
    - No evidence that larger amounts of fluids reduce the prevalence of acute renal failure in early postp.
  - Maintaining good cardiac subsystem
  - Renal dose of Dopa : controversial

Renal subsystem

- Management and treatment
  - Lasix
    - 1mg/kg up to 40 mg : q 6-12 hrs for 3 days
    - Double, quadruple dose up to 8mg/kg
    - 1-15mg/hr
  - Renal cocktail
    - 400mg lasix + 100ml of 20% mannitol
    - If serum osmol > 310mOsm/l : stop
    - 4hrs IV + 4hrs stop + 4hrs IV….
  - Renal replacement Tx