Coronary artery disease (CAD): still most common cardiac disease; number one cause of death in United States; percutaneous stents decreasing in use but still common; volume of coronary bypass surgery stable over last decade (=400,000/yr); higher incidence of CAD-related death in United States seen in early data, but incidence similar to that in Europe since 2000; incidence lower in France, possibly because of diet (resveratrol in red wine may be protective)

Stents vs bypass: study from New York demonstrated greater survival after coronary bypass for patients with 3- vessel or complex 2- vessel disease; current recommendation coronary surgery instead of drug-eluting stent for triple-vessel or complex double-vessel disease; better outcomes seen with coronary bypass surgery in patients with diabetes and CAD

Optimization of cardiac patient for noncardiac surgery: continue nitrates, β-blockers, and calcium channel blockers (CCB); continuation of aspirin usually recommended, but POISE-2 study questions this practice; continue statins; continue antihypertensive agents, except some angiotensin-converting enzyme (ACE) inhibitors and angiotensin-receptor blockers (ARBs); initiating β-blockers in perioperative period no longer recommended; vasoplegia related to ACE inhibitors and ARBs cause of concern

Preoperative cardiac concerns: anatomy — assess location of lesions; lesions in left main, left anterior descending (LAD), and circumflex coronary arteries considered pressure dependent; left ventricle at risk during hypotension; information on percentage of obstruction also helpful; valvular disease — aortic stenosis also pressure-dependent lesion and often present in combination with CAD; symptoms of heart failure — strongly related to outcome; optimize patient before surgery

Anticoagulants: increasingly used in patients with cardiovascular disease; desire to find substitute for warfarin led to development of 2 new classes of anticoagulants; direct thrombin inhibitors and factor Xa inhibitors highly potent; available for past 5 yr; not approved for valvular heart disease, so patients with artificial valves still taking warfarin; most other patients moving to new medications because of superior tolerance, compared with warfarin

Dabigatran (Pradax, Pradaxa, Prazaxa): first oral direct thrombin inhibitor; complications include perioperative bleeding, spontaneous bleeding, and stroke; indicated for patients with deep venous thrombosis, and those with atrial fibrillation and risk for embolization and cerebrovascular accident; taken by thousands of patients; does not require coagulation monitoring; degree of anticoagulation difficult to evaluate; has rapid onset, with half-life of 12 hr; cleared by kidneys; no reversal agent available until recently (prothrombin concentrates and factor VIIa not effective; case reports describe reversal with preoperative dialysis); eliminates option of regional anesthesia

Idarucizumab (Praxbind): reversal agent for dabigatran; recently approved by the Food and Drug Administration (FDA); although attempts made to take dabigatran off market, FDA instead chose to facilitate approval process for reversal agent; reverses effects of dabigatran within 4 hr; efficacy confirmed in RE-VERSE AD phase III study

Factor Xa inhibitors: rivaroxaban (Xarelto) developed first; apixaban (Eliquis) most commonly used; third drug (andexanet alpha) recently released; acute unstable coronary artery syndrome, which affects millions of patients, added as new indication; no coagulation monitoring required; administered in fixed dose; has rapid onset and half-life of 12 hr; metabolized primarily in liver, with some renal excretion

Bleeding related to factor Xa inhibitors: difficult to manage but less difficult than bleeding related to dabigatran; no specific reversal agent available; prothrombin complex concentrate (PCC) effective for management; fresh frozen plasma requires larger volumes; concentrated coagulation factors somewhat effective; factor VIIa may be used, if necessary; precludes use of regional anesthesia; data demonstrate reversal with PCC

Andexanet alpha: currently in development; not monoclonal antibody; direct antagonist that binds factor Xa activity; reversal of apixaban demonstrated in study; no complications observed in volunteers

Anesthesia management for cardiac patients: optimize patients preoperatively; inhalational anesthetics (plus low-dose opioids) currently preferred over high-dose narcotics alone; inhalational anesthetics precondition heart to provide protection against ischemia, help to avoid recall, and facilitate fast-tracking of patients and avoidance of prolonged intubation and ventilation

Protective effects of inhalational anesthetics: reduce afterload and preload, decrease contractility, and allow titration of blood pressure and control of hypertension, which creates conditions that favor myocardial oxygen balance; reperfusion injury after...
revascularization of heart less problematic; fewer arrhythmias occur; may protect and precondition heart against ischemia via mechanism similar to that of nitroglycerin

**Ischemic preconditioning:** heart becomes inefficient during short periods of ischemia, then quickly recovers when ischemia eliminated; alternating periods of ischemia and recovery cause heart to release protective agents that allow longer periods of ischemia

**Anesthetic preconditioning:** use of inhalational anesthetics during coronary cases found to yield better outcomes; mechanism not clearly understood; calcium changed, adenosine triphosphate channels opened, and nitroglycerine-like substances with nitric oxide released; protective effects supported by animal models

**Additional protective factors:** opioid receptors — administration of morphine provides protection; protection eliminated by reversal with naloxone

**Summary:** inhalational anesthetics associated with multiple mechanisms of protection, particularly in combination with narcotics or propofol

**Anesthetic preconditioning (continued):** anesthetic agent given before use of heart-lung machine or during ischemic period; coronary bypass performed off pump; any volatile anesthetic acceptable; release of biomarkers reduced with use of inhalational anesthetics; ventricular function appears to increase

**Remote preconditioning:** clamp placed to create ischemia in kidney or bowel; successful in animal models; protection provided to organs such as heart and brain; *simple technique* — application and inflation of blood pressure cuff on arm; during inflation, substances released to provide protection; inflation and release alternated (5 min on, 5 min off); technique controversial because recent studies indicated heart not protected during cardiac surgery, and because inflammatory processes triggered by cuff inflation may be harmful

**Preconditioning in noncardiac surgery for patients with CAD:** when techniques used in cardiac surgery applied, no protective effect observed; stress to patient during noncardiac surgery may be insufficient to produce demonstrable protective effect

**Anesthetic management for noncardiac procedures:** similar to that for cardiac surgery; use small doses of fentanyl, midazolam, and propofol to etomidate for induction; use inhalational agent as primary anesthetic; control hemodynamics with inhalational agent; propofol may be continued or administered intermittently by infusion; allows rapid awakening and extubation at end of procedure

**Central nervous system monitoring:** not often used for general coronary surgery; important for procedures on aortic arch and vessels to brain

**Thoracic epidural:** use complicated by administration of heparin and risk for epidural hematomas; anticoagulant and antiplatelet medications preclude use of epidural for many cardiac and noncardiac procedures

**Coronary artery surgery using heart-lung machine:** safe and effective; skillfully managed by perfusionists; considered gold standard; accounts for 60% to 70% of coronary procedures in United States and worldwide; left internal mammary anastomosed to LAD; veins used to bypass other vessels; patients cooled; heart stopped with potassium solution; patients fully anticoagulated and monitored; cardiac monitors withdrawn while surgeons operate on heart and repositioned after bypass

Anesthesia during bypass: perfusionist controls circulation and respiration; presence of anesthesiologists required to ensure continuation of anesthetic, monitoring of patient, observation of procedure, and communication with surgeon; at least one member of anesthesia team needed in operating room at all times

Duration of bypass: heart-lung machine works well for 3 to 4 hr; prolonged time on machine damages blood, causes abnormal clotting, damages kidneys, causes neurologic problems, and introduces bubbles and floating material into bloodstream (machine designed for short-term use only)

**Off-pump coronary surgery:** technically more difficult than heart-lung bypass; involves operating on beating heart using magnifying lenses; also more challenging for anesthesia team; patient normothermic and only partially heparinized; relies on preconditioning (anesthesia provider must maintain inhalational anesthetic); monitoring ischemia difficult while surgeons move heart; electrocardiography may or may not provide useful information; blood pressure varies greatly as surgeon manipulates heart

Sequence of anastomoses: first, left internal mammary artery anastomosed to LAD with heart flat; next, heart rolled to side and vein grafts attached; third, heart verticalized (pulled straight up and out of chest), which compromises venous return; anesthesia team administers medications and minimizes ischemia

Myocardial ischemia: indicated by ST segment depression, with heart rate 80 to 90 bpm; target heart rate 60 bpm (slower heart rate creates easier working conditions for surgeon, less work for heart, and less ischemia); treat by administering more anesthetic, more fentanyl, and perhaps 20 mg esmolol

Treatment of other conditions: *hypertension* — deepen anesthe-sia; administer nitroglycerin or CCB to treat underlying ischemia; abnormalities of regional wall motion — nitroglycerin treatment of choice; decreased blood pressure with ST segment depression — may necessitate temporarily ceasing manipulation of heart; phenylephrine drug of choice; if ST segment changes persist after blood pressure restored, administer nitroglycerin; treatments also apply to patients undergoing noncardiac surgery

Additional considerations for off-pump surgery: conversion to use of cardiopulmonary bypass during procedure rare and associated with poor outcomes; anesthesia team must attempt to maintain light anesthetic (considerable effort required); allows avoidance of complications of heart-lung machine; outcomes similar between techniques; superiority of one technique over other debated

**Coronary stents:** performed in catheterization laboratories in large volumes; patients with stents given dual therapy of aspirin plus another drug to prevent clotting of stent for 12 mo; use of third-generation bioabsorbable polymer stents should lower incidence of thrombosis; optimal duration of dual therapy debated (opinions of cardiologists trending toward longer period of time on dual therapy)

**Antiplatelet medications:** clopidogrel (Plavix) — prodrug metabolized in series of steps; metabolized poorly by some patients; interacts with P2Y12 receptor (adenosine diphosphate receptor) to affect platelet function; patients who metabolize clopidogrel poorly switched to other medications

Alternatives to clopidogrel: prasugrel (Effient) — metabolized in one step; nearly all patients metabolize to active drug; incidence of bleeding higher than with clopidogrel; ticagrelor (Brilinta) — directly affects P2Y12 receptor; not prodrug; not affected by metabolism; use increasing; cangrelor — intravenous short-acting medication; enables direct control of platelet function; designed for use in catheterization laboratory; useful as bridging medication during perioperative period

Concerns about ticagrelor: not as easily reversed as other antiplatelet medications; platelets usually used for reversal of antiplatelet effects; however, ticagrelor remains in bloodstream and binds to newly administered platelets; compared with other antiplatelet medications, reversal of ticagrelor requires more platelets and other factors

Study of cangrelor: recently approved by FDA; study demonstrated effectiveness in decreasing platelet function; decrease in function sustained during infusion; antiplatelet effect effectively reversed by discontinuing infusion; titratable drug that allows rapid reversal for surgery
Percutaneous aortic valve replacement: typical patient has end-stage aortic stenosis, CAD, on maximal medical therapy, and has been rejected for cardiac surgery; in United States, procedure usually performed under general anesthesia; trans-femoral approach involves retrograde approach to heart and requires working against blood flow; approach through apex of heart requires cardiac surgeon and working antegrade; apex approach back-up procedure (groin approach primary procedure); retrograde approach requires induced ventricular tachycardia lasting <15 sec; mortality at 30 days 6% to 8.5%

Mitral valve clipping: new procedure for patients with mitral regurgitation; atrial septum crossed and mitral valve clipped; has potential for catastrophic complications

**Suggested Reading**


**Acknowledgments**

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1. Which of the following is NOT recommended when optimizing cardiac patients for noncardiac surgery?
   (A) Initiate β-blockers in the perioperative period if the patient is not already taking them**
   (B) Continue β-blockers if the patient is taking them
   (C) Continue calcium channel blockers
   (D) Continue nitrates

2. All the following are sites of pressure-dependent coronary lesions, EXCEPT:
   (A) Right main coronary artery**
   (B) Left main coronary artery
   (C) Left anterior coronary artery
   (D) Circumflex coronary arteries

3. Which of the following is a true statement about dabigatran?
   (A) It is a factor Xa inhibitor
   (B) It is indicated for patients with deep venous thrombosis**
   (C) It has a half-life of 48 hr
   (D) It is cleared by the liver

4. Inhalational anesthetics have which of the following cardiovascular effects?
   (A) Increased preload
   (B) Increased afterload
   (C) Decreased cardiac contractility**
   (D) Increased incidence of arrhythmias

5. Which of the following is NOT an accurate statement about the use of preconditioning in patients with coronary artery disease?
   (A) Use of inhalational anesthetics during coronary procedures improves outcomes
   (B) Associated with increased ventricular function
   (C) Inhalational anesthetics reduce the release of biomarkers
   (D) Benefits are similar among patients undergoing noncardiac surgery and cardiac surgery**

6. Which of the following is a true statement about the use of heart-lung bypass for coronary surgery?
   (A) It is considered the gold standard**
   (B) Patients can be safely kept on bypass for ≤8 hr
   (C) The presence of the anesthesia team is not required while the heart-lung machine is in use
   (D) Patient normothermia is maintained during the procedure

7. Which of the following are challenges associated with off-pump cardiac surgery?
   1. Electrocardiography may not provide useful information
   2. Patients are fully heparinized
   3. Blood pressure varies greatly as the surgeon manipulates the heart
   4. Patients need to kept hypothermic
   5. Ischemia is difficult to monitor
   (A) 1,2 (B) 3,4 (C) 1,3,5** (D) 2,3,4

8. Literature addressing the length of time patients should remain on dual therapy following placement of coronary stents suggests that:
   (A) The optimal duration of dual therapy is 6 mo
   (B) The optimal duration of dual therapy is 12 mo
   (C) The optimal duration of dual therapy is 30 mo
   (D) There is no clear consensus on optimal duration of dual therapy**

9. Which of the following antiplatelet medications is an intravenous short-acting agent suitable for bridging during the perioperative period?
   (A) Clopidogrel
   (B) Cangrelor**
   (C) Ticagrelor
   (D) Prasugrel

10. Which of the following is the most accurate statement about percutaneous aortic valve replacement?
    (A) In the United States, it is usually performed under monitored anesthesia care
    (B) The retrograde approach requires induced ventricular tachycardia lasting ≤1 min
    (C) The approach through the apex of the heart requires a cardiac surgeon**
    (D) Mortality at 30 days is 20%

Answers to Audio Digest Anesthesiology Volume 58, Issue 14: 1-C, 2-D, 3-D, 4-D, 5-D, 6-A, 7-C, 8-A, 9-A, 10-C