Perioperative Management of Rhythm and Conduction Disorders

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Module Updated: 2013-03-21
CME Expiration: 2016-03-21

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1. Elements of Risk

Recognize the prevalence, clinical significance, and epidemiology of periopeative arrhythmias and conduction disorders.

1.1 Recognize that perioperative arrhythmias are common in patients undergoing various types of surgeries.

**Recommendations**

- Recognize that perioperative arrhythmias and conduction disturbances are common in patients undergoing various surgical procedures but are most common in cardiac surgery.

**Evidence**

- Although >80% of patients may have transient postoperative arrhythmias on telemetry monitoring, <5% of these incidents are of clinical importance (1).
- Atrial fibrillation is the most common major arrhythmia noted after open cardiac, non-cardiac thoracic, and major abdominal surgeries (2; 3).
- The incidence of atrial fibrillation was estimated to be 50% in patients undergoing cardiac surgery (4; 5; 6; 7), 8% to 13% in patients undergoing non-cardiac thoracic or abdominal surgeries (3; 8; 9; 10; 11).
- A 1991 meta-analysis of medications for supraventricular tachycardia after cardiac surgery noted atrial fibrillation in 27% inpatients undergoing CABG (12).
- In a retrospective cohort study of 19,497 patients undergoing isolated CABG, 28.5% developed postoperative atrial fibrillation (13).
- A prospective study of 513 vascular surgery patients found that new-onset arrhythmias were frequently detected with 72-hour continuous ECG monitoring in patients without prior history of arrhythmias. Atrial fibrillation was detected in 4% of patients, ventricular tachycardia in 7%, SVT in 1%, and ventricular fibrillation in 0.2% (14).
- The incidence of post-CABG ventricular tachyarrhythmias (ventricular tachycardia or fibrillation) was 1.6% in a case-control study based on a prospectively collected database of 4411 consecutive patients (15).
- In a prospectively obtained database of 4748 patients undergoing non-emergent CABG, 45 patients (0.95%) had sustained ventricular tachycardia or ventricular fibrillation in the early postoperative time period (16).
- In a retrospective study of 354 patients admitted to the surgical ICU after non-cardiac surgery, 30 (8.5%) patients developed atrial arrhythmias (17).
- In a review of 1614 patients undergoing CABG, the incidence of prolonged postoperative bradyarrhythmias (mainly complete heart block) was 0.8% (18). A smaller observational study of 93 patients found the incidence of complete AV block to be 4% (19).
- Postoperative bradyarrhythmias after valvular surgery occur in up to 40% of patients undergoing tricuspid valvular surgery, 10% of patients undergoing aortic valve surgery, and 2% to 5% of patients undergoing mitral valve surgery (20; 21; 22; 23; 24). Higher risks are associated with multiple valve replacement operations (20).
- Intraoperative bradycardic events have been reported in up to 20% of patients undergoing shoulder arthroscopy in the sitting position under interscalene block anesthesia, attributed to the Bezold-Jarisch reflex (25).

**Rationale**

- Postoperative arrhythmias and conduction disturbances are common in high-risk patients, but many events are benign and of limited clinical importance.

**Comments**
• It is likely that studies of non-cardiac surgery underestimate the true prevalence of perioperative arrhythmias, because many do not extend continuous cardiac monitoring into the second or third postoperative day, and the peak incidence of atrial fibrillation is between postoperative days 2 and 4 (26).

1.2 Recognize that perioperative arrhythmias are associated with increased cardiovascular morbidity and mortality.

Recommendations

• Recognize that perioperative cardiac arrest is associated with decreased survival to hospital discharge.
• Recognize that perioperative atrial fibrillation is associated with worse in-hospital and 5-year survival, as well as increased cardiovascular morbidity, including stroke and HF.
• Recognize that arrhythmias also increase length of hospital stay and costs.

Evidence

• A single-center, retrospective analysis comparing 994 patients with atrial fibrillation after CABG to 5481 patients who did not develop postoperative atrial fibrillation identified this rhythm as an independent predictor of long-term mortality (4- to 5-year follow-up; OR, 3.4). The presence of postoperative atrial fibrillation also was associated with a higher in-hospital mortality (OR, 1.7) and stroke risk (OR, 2.0) (27).
• In a retrospective study of 762 patients undergoing surgery for mitral valve regurgitation, postoperative atrial fibrillation predicted HF, stroke, and late atrial fibrillation during a 10-year follow-up period (28).
• In a retrospective cohort study of 19,497 patients undergoing isolated CABG in Australian hospitals, those who developed atrial fibrillation had an increased risk of stroke, new-onset renal failure, infections, GI complications, and decreased long-term survival, but not 30-day mortality. Long-term survival at 7 years after CABG was 80.6% in patients with postoperative atrial fibrillation vs. 87% in patients without (13).
• A prospective study of 513 vascular surgery patients found that new-onset perioperative arrhythmias were independently associated (HR, 2.2) with worse outcomes, after controlling for myocardial ischemia. This study also reported that the HR was worse for SVT (HR, 3.0 [CI, 1.5 to 6.2]) than for ventricular tachycardia (HR, 1.7 [CI, 0.9 to 3.6]) (14).
• Multivariate analysis of a retrospective study of 223 cases of perioperative cardiac arrest in 518,294 patients undergoing non-cardiac surgery found several factors that predicted decreased survival to hospital discharge. These predictive factors included perioperative bleeding causing cardiac arrest (OR, 0.2), protracted hypotension (OR, 3.0), diabetes (OR, 0.2), and arrests that occurred during non-standard working hours (OR, 0.2). Overall survival to hospital discharge after cardiac arrest was 34% (29).

Rationale

• Appreciation of potential adverse outcomes with perioperative arrhythmias should prompt closer postoperative follow-up and optimization of therapy.

1.3 Understand which patient-related and procedure-related factors affect the risk of perioperative arrhythmias.

Recommendations

• Recognize that the following patient-related factors increase the risk for perioperative arrhythmias: increasing age, history of arrhythmia, symptomatic or asymptomatic HF or systolic or diastolic cardiac dysfunction, certain ECG abnormalities, electrolyte imbalances, and medication use.
• Recognize that the following procedures are associated with a higher risk for perioperative arrhythmias: open cardiac surgery, valvular surgery, thoracotomy, or other intrathoracic surgery.
• Anticipate a postoperative atrial arrhythmia risk of 30% to 50% in most patients undergoing open cardiac surgery, compared with a risk of 8% to 13% in patients undergoing high-risk non-cardiac surgical procedures.

Evidence

• Patient factors that increase the risk of developing perioperative arrhythmias include advancing age (6; 20; 30; 31; 32; 33), obesity (34), a history of arrhythmias (5; 33; 35), HF (33; 36; 37), CAD, hypertension (38), enlarged atria (39), atrial fibrosis (40), and preoperative ECG abnormalities (5; 33; 41; 42).

• Open cardiac procedures lead to a substantially higher risk of perioperative arrhythmias when compared with non-cardiac surgery. Valvular cardiac surgeries, especially in combination with CABG (4; 39), and aortic arch surgery have the highest risk (4; 5; 6; 7; 43).

• The likelihood of perioperative arrhythmias (most commonly atrial fibrillation) after open cardiac surgery exceeds 30% in patients without valvular intervention, and upwards of 50% in patients undergoing valvular surgery (4; 5; 6; 7). Postoperative vasopressor use has been associated with an even higher risk of developing postoperative atrial fibrillation (44).

• A retrospective review of 800 consecutive patients undergoing isolated CABG found that the risk for postoperative SVT was increased in patients aged 65 years or older compared with patients aged less than 60 years, in those with a history of atrial arrhythmias when compared with patients without a history of arrhythmia (45% vs. 22%; P<0.002), and in patients with premature atrial contractions on the preoperative ECG compared with those without (48% vs. 22%; P<0.002) (5). Diastolic dysfunction (left ventricular end diastolic pressure >20 mm Hg) was also independently associated with an increased risk for postoperative supraventricular arrhythmias (5).

• In a prospective cohort of 4181 patients aged 50 years or older who had major non-emergent, non-cardiac procedures and were in sinus rhythm preoperatively, the OR for developing postoperative supraventricular arrhythmia in patients aged over 70 years compared with younger patients was 1.3 (CI, 1.0 to 1.7), in patients with a history of atrial arrhythmias was 3.4 (CI, 2.4 to 4.8), in those with preoperative HF was 1.7 (CI, 1.1 to 2.7), and in those with premature atrial beats was 2.1 (CI, 1.3 to 3.4). Overall, 7.6% had perioperative supraventricular arrhythmias that led to an adjusted 33% increase in length of stay (33).

Rationale

• Awareness of risk factors allows for appropriate monitoring.

• Modifiable causes of increased risk such as decompensated HF or electrolyte imbalances, should be treated preoperatively.
2. Whom and How to Assess

Recognize multiple subgroups that are at increased risk for perioperative arrhythmic complications. 

2.1 Recognize that advancing age is the most important risk factor for development of postoperative arrhythmias.

Recommendations

- Be aware of the increasing risk for postoperative arrhythmia in the elderly population, and monitor expectantly.
- Identify modifiable risk factors, such as hypokalemia and preoperative drugs (e.g., β-blockers) in the elderly.

Evidence

- In a series of 5807 patients undergoing CABG, the prevalence of atrial fibrillation and flutter was directly related to age at operation and varied from 3.7% in patients aged under 40 years to 27.7% in patients aged over 70 years (6).
- A multicenter, prospective, observational study of 4657 patients undergoing CABG showed that for each 10-year increase in age, there was an OR of 1.75 for developing atrial fibrillation (CI, 1.6 to 1.9) (45).
- A retrospective review of risk factors for postoperative atrial fibrillation found that age over 60 years was the strongest predictor of postoperative atrial fibrillation (OR, 2.5) in patients undergoing major elective thoracic surgery (30).
- In an observational study of 570 patients undergoing CABG, older patients had an increased risk for developing postoperative atrial fibrillation. Patients aged 70 to 80 years had an OR of 2 on multivariate logistic regression analysis, and patients aged over 80 had an OR of 3 (31).
- A prospective observational study of more than 10,000 patients undergoing both CABG and open cardiac valvular surgery found that patients aged 75 years or older were more likely to receive a permanent pacemaker during the index hospitalization (OR, 3.0 [CI, 2.0 to 4.4]) (20).
- In a retrospective review of 800 patients who had isolated CABG, the mean age of patients who developed postoperative SVT was 65 years compared with 60 years in patients who did not develop an arrhythmia (P<0.002) (5).
- In a prospective cohort of 4181 patients aged 50 years or older who had major non-emergent, non-cardiac procedures and were in sinus rhythm preoperatively, patients aged over 70 years were more likely than younger patients to develop postoperative supraventricular arrhythmias (OR, 1.3 [CI, 1.0 to 1.7]) (33).

Rationale

- Risk for arrhythmias can translate into risk for extended hospital stay, increased costs, and increased mortality.
- Awareness of risk factors allows for close monitoring and appropriate interventions.

2.2 Consider a history of arrhythmia to be an important risk factor for development of postoperative arrhythmias.

Recommendations

- Be alert for the development of new postoperative arrhythmias in patients with a history of arrhythmia.
- Identify modifiable preoperative factors, such as serum potassium level and the use of β-blockers, in patients with a history of arrhythmias.

Evidence
In a retrospective review of 800 patients undergoing CABG, the risk for postoperative SVT was increased in patients with a history of atrial arrhythmias when compared with patients without a history of arrhythmia (45% vs. 22%; P<0.002) (5).

A review of 1851 patients undergoing CABG found that a prior history of atrial fibrillation was associated with an increased risk of sustained postoperative atrial fibrillation (adjusted OR, 3.7 [CI, 2.3 to 6.0]) (46).

A consecutive series of 230 male patients undergoing major non-cardiac surgery showed that preoperative arrhythmias were associated with the occurrence of intraoperative arrhythmias (OR, 7.3 [CI, 3.3 to 16.0]) and postoperative arrhythmias (OR, 6.4 [CI, 2.7 to 15.0]) (35).

In a prospective cohort of 4181 patients aged 50 years or older who had major, non-emergent non-cardiac procedures and were preoperatively in sinus rhythm, a history of atrial arrhythmias was associated with the development of postoperative supraventricular arrhythmia (OR, 3.4 [CI, 2.4 to 4.8]) (33).

An analysis of 2588 patients undergoing non-cardiac thoracic surgery identified a history of arrhythmia as a risk factor for developing postoperative atrial fibrillation (RR, 1.92 [CI, 1.22 to 3.02]) (47).

Rationale

- Awareness of risk factors for postoperative complications allows for preparation in the event of the manifestation of arrhythmias.

2.3 Recognize HF and asymptomatic systolic or diastolic dysfunction as risk factors for the development of postoperative arrhythmias.

Recommendations

- Evaluate patients for HF before surgery to estimate the risk for pulmonary edema for postoperative arrhythmia.
- Consider patients with a low EF undergoing cardiac and high-risk non-cardiac procedures to have an increased risk for ventricular arrhythmias.
- Recognize that patients with chronic elevation of left ventricular filling pressure (enlarged left atrium) are at risk for postoperative SVT, including atrial fibrillation.

Evidence

- In a prospective observational cohort of 4181 patients aged 50 years or older who had major non-emergent, non-cardiac procedures and were preoperatively in sinus rhythm, the presence of preoperative HF was independently associated with the development of postoperative supraventricular arrhythmia (OR, 1.7 [CI, 1.1 to 2.7]) (33).
- In a retrospective review of 800 consecutive patients undergoing CABG, the risk for postoperative SVT was independently associated with diastolic dysfunction (left ventricular end diastolic pressure >20 mm Hg) (5).
- In a study of more than 2000 patients undergoing CABG, the risk of postoperative ventricular tachycardia was 0.7% (16 patients); however, all 16 patients had significant preoperative left ventricular dysfunction, and 14 patients had EFs <30% (37).
- A prospective evaluation of 109 patients undergoing elective or urgent cardiac bypass surgery did not show any significant increase in risk for postoperative ventricular arrhythmia in patients with systolic dysfunction (EF <50%) (48).
- A case-control study performed on a prospective cohort of 4411 consecutive patients undergoing CABG found that a moderately impaired or poor EF increased the risk of postoperative ventricular tachyarrhythmias (OR, 1.72) (15).
- A prospective study of 4748 patients undergoing non-emergent CABG found that 0.95% of patients had a postoperative ventricular arrhythmia; initial episodes occurred a mean of 3.9 days after surgery. A low EF (<35%) was a significant risk factor for early postoperative ventricular tachyarrhythmias (OR, 4.8) compared with patients with EF >50% (16).

Rationale
Perioperative Management of Rhythm and Conduction Disorders

- Treatment of symptomatic HF may reduce the risk for postoperative arrhythmias and for HF complications.
- Preoperative identification of patients at high risk for postoperative atrial fibrillation allows for preventive medical therapy and heightened awareness.

Comments

- A study of 187 patients undergoing cardiac surgery found that patients experiencing postoperative atrial fibrillation had a significantly higher B-type natriuretic peptide level (615 pg/mL vs. 444 pg/mL; \( P=0.005 \)) (49).

2.4 Appreciate that postoperative arrhythmias are more common after open cardiac procedures than non-cardiac surgeries.

Recommendations

- Recognize that procedure-related arrhythmia risk is much higher in cardiac surgery than in non-cardiac surgery.
- Anticipate a postoperative atrial arrhythmia risk of 30% to 50% in most patients undergoing open cardiac surgery, compared with an 8% to 13% risk in other high-risk non-cardiac surgical procedures.
- See table Cardiac Risk of Non-cardiac Surgical Procedures.

Evidence

- The likelihood of perioperative arrhythmias (most commonly atrial fibrillation) after open cardiac surgery exceeds 30% in patients without valvular intervention, and upwards of 50% in patients undergoing valvular surgery (4; 5; 6; 7).
- A meta-analysis of more than 20,000 patients undergoing CABG enrolled in 24 trials showed a mean incidence of atrial fibrillation of 27% (12).
- A study of 84 patients undergoing minimally invasive aortic and mitral valve replacements reported rates of postoperative atrial fibrillation to be 27% and 12%, respectively (55).
- In a cohort of 4181 patients prospectively observed after major non-emergency, non-cardiac procedures who were in normal sinus rhythm before surgery, 7.6% had perioperative supraventricular arrhythmias that led to an adjusted 33% increase in length of stay (33).
- A study of 226 patients undergoing colorectal surgery found that 13% had a postoperative arrhythmia (either supraventricular and ventricular) (3).
- A prospective cohort study (20) of over 10,000 patients who had cardiac surgery evaluated risk factors for the need for a permanent pacemaker. Valve replacement surgery was associated with pacemaker need (OR, 5.8 [CI, 3.9 to 8.7] for the aortic valve; 4.9 [CI, 3.1 to 7.8] for the mitral valve; 8.0 [CI, 5.5 to 11.9] for the tricuspid valve; 8.9 [CI, 5.5 to 14.6] for 2 valves; and 7.5 [CI, 2.9 to 19.3] for 3 valves). Other risk factors included repeat operation (OR, 2.4 [CI, 1.8 to 3.3]) and mitral valve annular reconstruction (OR, 2.4 [CI, 1.4 to 4.2]).
- Retrospective studies from the surgical literature involving 100 to 125 patients have shown a 1% to 10% risk for high-grade AV block requiring permanent pacemaker implantation after aortic valve replacement (21; 22).
- A retrospective review of 389 patients undergoing aortic valve replacement showed that patients with a preoperative bundle branch block had an increased risk (9.7%) of the composite end point of sudden cardiac death, complete AV block, or syncope over 1 year of postsurgical follow-up compared with patients with no pre- or postoperative bundle branch block (1.6%) (56).
- In a retrospective review of 115 mitral valve replacement surgeries, the incidence of postoperative complete heart block was 6%, with 3 patients (2.6%) requiring permanent pacemaker implantation (23).

Rationale

- Well-performed studies consistently show a significant increase in the risk for perioperative arrhythmias after open cardiac surgery compared with other surgeries.
Comments

- Postoperative vasopressor use has been associated with an even higher risk of developing postoperative atrial fibrillation (44).
- Because the risk for arrhythmia complicating cardiac surgery is exponentially higher, many of the studies on arrhythmia prevention and management are based on this population.

2.5 Recognize the lack of validated instruments to predict the risk for perioperative arrhythmias. 

Recommendations

- Recognize that clinical prediction rules predict a composite cardiac outcome and do not separately predict the risk for arrhythmia.

Evidence

- The 2007 ACC/AHA guidelines on perioperative cardiovascular evaluation and care for non-cardiac surgery subdivide non-cardiac procedures into risk categories of low, intermediate, and high based on risk for cardiac death or myocardial infarction, which may be extrapolated to risk for arrhythmia (57).

Rationale

- There is no validated instrument to specifically calculate the risk for perioperative arrhythmia.

2.6 Obtain appropriate preoperative testing as dictated by patient risk factors and type of surgical procedure. 

Recommendations

- Obtain a baseline ECG and electrolyte panel before all open cardiac procedures and intermediate and high-risk non-cardiac surgical procedures.
- Consider evaluating patients undergoing cardiac surgery with transthoracic echocardiography to assess left atrial volume and risk for postoperative atrial fibrillation.
- High-value care: Do not obtain a routine ECG or electrolyte panel before procedures at low surgical risk for arrhythmia, with the possible exception of patients with a history of coronary disease or diabetes.
- See table Cardiac Risk of Non-cardiac Surgical Procedures.

Evidence

- In a prospective case-control study of more than 2400 patients, a serum potassium level of <3.5 µmol/L was associated with a more than two-fold increase in the risk for perioperative arrhythmias (58).
- A randomized trial compared preoperative testing (including ECG, electrolytes, and CBC) with no testing in 18,189 patients undergoing cataract surgery (low-risk non-cardiac surgery). The complication rate was the same in both groups, including rates of intra- and postoperative events (59).
- The 2007 ACC/AHA guideline on perioperative cardiac testing and care recommended preoperative testing for patients with recent episodes of chest pain (or ischemic equivalent) who are undergoing cardiac procedures, intermediate-risk procedures, or high-risk procedures. The guideline stated that ECG testing is a class II recommendation (i.e., conflicting opinion exists regarding usefulness of test) in patients with known prior coronary disease or diabetes mellitus undergoing low-risk procedures and in men aged over 45 years and women aged over 55 years with two or more risk factors for CAD. The guideline recommended against routine preoperative ECG testing before low-risk procedures in low-risk patients (57).
- A study of 93 patients undergoing CABG observed that atrial dimension by transesophageal echocardiography correlated with increased risk for postoperative atrial fibrillation (OR, 1.75 [CI, 1.03 to 2.96]; P=0.038)(60).
EF by echocardiography has not been conclusively shown to predict postoperative arrhythmias; thus, routine echocardiography is not recommended for this indication (see information on active HF as a risk factor for the development of postoperative arrhythmias).

**Rationale**

- Appropriate targeted preoperative testing can identify patients at risk for postoperative arrhythmias and other complications.

### 2.7 Look for preoperative ECG abnormalities, which place patients at increased risk for postoperative arrhythmias.

**Recommendations**

- Obtain an ECG for patients undergoing CABG and high- and intermediate-risk surgical procedures and look for risk factors for perioperative arrhythmias, such as:
  - Atrial abnormalities
  - Intra-atrial conduction delay
  - Premature atrial contractions
  - Left bundle branch block
- Do not consider intraventricular conduction delays or bifascicular block as risk factors for postoperative bradyarrhythmias in patients undergoing non-cardiac surgery; however, a complete left bundle branch block in patients undergoing CABG may be an exception.

**Evidence**

- In a retrospective review of 800 patients who had isolated CABG, the risk for postoperative SVT was increased in patients with premature atrial contractions on the preoperative ECG compared with those without (48% vs. 22%; P<0.002) (5).
- In a prospective cohort of 4181 patients aged 50 years or older who had major non-emergent, non-cardiac procedures and who were preoperatively in sinus rhythm, patients with premature atrial complexes on preoperative ECG were more likely to develop postoperative supraventricular arrhythmias (OR, 2.1 [CI, 1.3 to 3.4]) (33).
- A prospective analysis of 44 patients with right bundle branch block and left-axis deviation undergoing 52 non-cardiac surgical procedures showed only one episode of complete heart block, which was transient (50).
- Several small (30 to 98 patients) studies have failed to show an increase in the perioperative incidence of new high-grade heart block in patients with preoperative bifascicular block on ECG (51; 52; 53).
- A retrospective study compared 455 patients undergoing non-cardiac surgery who had preoperative bundle branch block with surgical patients without bundle branch block and found no significant difference in arrhythmia, cardiac complications, or mortality between patients with bundle branch block and controls (54).
- In a study of 1614 patients undergoing coronary bypass surgery, preoperative left bundle branch block and age over 64 years were independent predictors of severe and prolonged postoperative bradyarrhythmias (mainly complete heart block). However, the incidence was low (0.8%) (18).

**Rationale**

- Knowledge of potential risk can allow for prompt recognition and treatment of tachyarrhythmias and bradyarrhythmias.

**Comments**

- There is a theoretical risk for complete heart block if pulmonary arterial catheterization is planned during surgery in a patient with preexisting left bundle branch block; however, this risk is not substantiated by clinical evidence at this time.
3. Interventions to Decrease Risk

Identify patients who may benefit from interventions to decrease the risk for perioperative arrhythmias, and recognize interventions that are unlikely to be beneficial.

3.1 Administer β-blocking drugs to all patients before cardiac surgery and consider prophylactic therapy with amiodarone in select patients. Continue β-blockers in patients already on them.

**Recommendations**
- Administer preoperative β-blockers (including sotalol) in patients undergoing cardiac surgery to prevent atrial fibrillation.
- Consider other therapies in patients who cannot tolerate β-blockers including amiodarone, magnesium, and atrial pacing.
- Consider adding β-blockers in patients having non-cardiac surgery (in the absence of contraindications) to treat suboptimal hypertension or control heart rate.
- Recognize that routine use of perioperative β-blockers in patients undergoing non-cardiac surgery who are not at high risk for cardiac outcomes may result in excess mortality and morbidity.
- Do not routinely use preoperative steroids to reduce the risk of atrial fibrillation.
- See table Cardiac Risk of Non-cardiac Surgical Procedures.
- See module Atrial Fibrillation.

**Evidence**
- A 2013 Cochrane review of interventions to prevent postoperative atrial fibrillation in patients undergoing heart surgery included 118 studies with 17,364 participants. Several interventions reduced the rate of postoperative atrial fibrillation; β-blockers (OR, 0.33 [CI, 0.26 to 0.43]) and sotalol (OR, 0.34 [CI, 0.26 to 0.43]) were most effective, followed by amiodarone (OR, 0.43 [CI, 0.34 to 0.54]), magnesium (OR, 0.55 [CI, 0.41 to 0.73]), atrial pacing (OR, 0.47 [CI, 0.36 to 0.61]) and posterior pericardiotomy (OR, 0.35 [CI 0.18 to 0.67]). The interventions did not significantly reduce length of stay or mortality.
- A 2005 guideline from the American College of Chest Physicians recommended β-blockers to prevent atrial fibrillation after cardiac surgery.
- A 2011 guideline from the Society of Thoracic Surgeons on prophylaxis for atrial fibrillation in patients undergoing general thoracic surgery recommends continuing β-blockers in patients who are receiving them, consideration of amiodarone in patients undergoing thoracic surgery other than pneumonectomy, and consideration of magnesium.
- A 2006 systematic review of the effect of amiodarone on morbidity and length of stay after cardiac surgery included 10 trials with 1744 patients. Treatment with amiodarone decreased rates of atrial fibrillation/flutter (RR, 0.64 [CI, 0.55 to 0.75]), stroke (RR, 0.39 [CI, 0.21 to 0.76]), and ventricular arrhythmias (RR, 0.42 [CI, 0.28 to 0.63]) and decreased length of stay by a mean of 0.63 days (CI, 0.23 to 1.03 days).
- A 2008 systematic review of the effects of β-blockers in patients undergoing non-cardiac surgery included 33 trials with 12,306 participants. β-blockers were not associated with reductions in mortality, HF, or cardiovascular mortality but did decrease non-fatal myocardial infarction (NNT, 63) and increase non-fatal stroke (NNH, 293).
- A small (n=86) prospective, randomized, placebo-controlled trial of perioperative, high-dose steroids in patients undergoing CABG showed a significant reduction in postoperative atrial fibrillation (21% in the steroid group vs. 51% in the placebo group) but at the cost of a higher postoperative complication rate.
• A 2008 meta-analysis of steroid use in patients undergoing cardiopulmonary bypass included 44 trials with 3205 patients. Steroid use resulted in lower rates of new atrial fibrillation (RR, 0.71 [CI, 0.59 to 0.87]) as well as postoperative bleeding and time in the ICU (78).

Rationale
• β-blockers are considered first-line therapy for prevention of atrial fibrillation in cardiac surgery.
• Amiodarone is emerging as a safe and effective prophylaxis for SVT in the perioperative period but has not been shown to be superior to β-blockers.
• Routine use of β-blockers perioperatively may cause more harm than benefit in low-risk patients.

Comments
• Direct comparisons of amiodarone and β-blockers for prevention of atrial fibrillation show equal efficacy, but trials have been small and methodologically flawed.
• Procainamide, propafenone, and digoxin have not been proven effective in reducing perioperative SVT after CABG; calcium-channel blockers may prevent postoperative atrial fibrillation.
• Despite concerns about possible bradyarrhythmias, hepatic toxicity, and pulmonary toxicity with chronic amiodarone therapy, no study has conclusively linked amiodarone use in the preoperative period with these adverse effects, possibly because of shorter duration of use.

3.2 Add statins preoperatively to reduce the incidence of atrial fibrillation in cardiac surgery. 

Recommendations
• Initiate statin therapy preoperatively in all patients before cardiac surgery if they are not already receiving it, in the absence of contraindications.

Evidence
• A 2012 systematic review of perioperative statin therapy included 15 randomized trials with 2292 patients. In patients undergoing cardiac surgery, statins decreased the risk of atrial fibrillation (NNT, 6; RR, 0.56 [CI, 0.45 to 0.69]). In patients undergoing cardiac and non-cardiac surgery, statins decreased the risk of myocardial infarction (NNT, 23; RR, 0.53 [CI, 0.38 to 0.74]) but not death (RR, 0.62 [CI, 0.34 to 1.14]), and reduced the mean length of hospital stay (79).
• A 2012 Cochrane review of statin therapy initiated before cardiac surgery included 11 randomized clinical trials with a total of 984 patients. Statin treatment reduced the incidence of postoperative atrial fibrillation (OR, 0.4 [CI, 0.29 to 0.55]) and decreased length of hospital stay, but did not change short-term mortality or risk of stroke, and did not significantly reduce myocardial infarction (OR, 0.52 [CI, 0.2 to 1.3]) (80).

Rationale
• Statins reduce perioperative arrhythmias, possibly due to anti-inflammatory effects.

3.3 Recognize the need for appropriate preoperative discontinuation of long-term oral anticoagulation therapy for patients with chronic atrial fibrillation, metallic valvular prostheses, or other high thromboembolic risk states. 

Recommendations
• Base the management of patients with chronic atrial fibrillation on the underlying thromboembolic risk.
• Stop warfarin 5 days before surgery in patients at low thromboembolic risk; resume warfarin 12 to 24 hours after surgery if hemostasis is achieved.
• Provide ‘bridging therapy’ with intravenous heparin or low-molecular-weight heparin for patients at high thromboembolic risk including patients with:
  • Mechanical heart valves
  • Stroke or TIA within 6 months or venous thromboembolism within 3 months
- CHADS$_2$ score of 5 or 6
- Rheumatic heart disease
- Severe thrombophilia
- See table Risk Stratification for Perioperative Thromboembolism.

Evidence
- A 2012 guideline from the American College of Chest Physicians practice on perioperative management of antithrombotic therapy recommended stopping vitamin K antagonists 5 days before surgery in patients whose anticoagulation can be interrupted, and resuming 12 to 24 hours after surgery in the absence of bleeding. The guideline also recommended bridging therapy with patients with mechanical heart valves and those at high risk for recurrent thromboembolism, including those with recent stroke, TIA, or venous thromboembolism, those with CHADS$_2$ score of 5 or 6, those with mechanical heart valves, and those with severe thrombophilia (65).
- In 385 patients aged over 75 years who were studied in the Stroke Prevention in Atrial Fibrillation-II trial (non-valvular atrial fibrillation), the annual risk for stroke while warfarin is withdrawn was 4.8%, translating into a stroke risk of 0.07% over 5 days (66).
- A cohort study reported outcomes of 650 patients at high risk for thromboembolism (due to chronic atrial fibrillation, prior embolism, or mechanical heart valves) who underwent invasive procedures and received bridging therapy with dalteparin. Patients were followed for a mean of 14 days. In patients undergoing procedures without high risk of bleeding, the rate of major bleeding was 0.7% and the rate of thromboembolism was 0.4%, and 5.9% of patients did not receive at least 1 dose of dalteparin due to bleeding. In patients undergoing procedures with high-risk of bleeding, 1.8% of patients had major bleeding and 1.8% of patients died, possibly due to thromboembolism (67).
- A multicenter cohort study in 1024 individuals evaluated the safety of discontinuing warfarin for patients undergoing invasive procedures, including patients with atrial fibrillation, venous thrombembolism, and mechanical heart valves. Few patients (8.3%) received bridging anticoagulation. The 30-day post-procedure rate of thromboembolic events was 0.7% (CI, 0.3% to 1.4%) and the rate of major bleeding was 0.6% and mostly involved patients who had received bridging anticoagulation (68).
- A cohort study evaluating the safety of bridging therapy in patients with a known high risk for thromboembolism (atrial fibrillation or mechanical heart valves) undergoing invasive procedures evaluated the efficacy of subcutaneous LMWH. The rate of thromboembolism was 3.6% (largely in patients in whom anticoagulation was deferred secondary to bleeding), and the rate of major bleeding was 6.7%. One third of the major bleeding episodes occurred during LMWH administration (69).

Rationale
- Most patients in chronic non-valvular atrial fibrillation have a low risk for thromboembolism in the short term (e.g., 5 days preoperatively).
- Patients at high risk should have bridging therapy while off oral anticoagulants, because even the short-term risk for thromboembolism is relatively high.

Comments
- For urgent procedures, rapid reversal of anticoagulation with vitamin K (if surgery is planned within 24 hours) or fresh frozen plasma (if surgery is planned immediately) is appropriate to minimize bleeding risk (70; 71).
- Most patients in atrial fibrillation are also receiving a rate-controlling agent that should be continued up until and through the surgical procedure, with a conversion to intravenous dosing, if necessary, while the patient is unable to receive oral drugs.

3.4 Identify any previously implanted pacemakers or implantable cardioverter-defibrillators, and seek qualified guidance for their management.
Recommendations

• Consult an electrophysiology specialist for patients with an ICD or pacemaker before and after surgical procedures.

Evidence

• Electrocautery is a well-known source of electromagnetic interference, and it has been reported to cause inappropriate ICD therapy delivery and pacemaker inhibition (62).
• The 2007 ACC/AHA guidelines recommended pacemaker interrogation before and after surgical procedures and programming an ICD off before surgery and on again postoperatively to avoid unwanted discharges. The guideline stated that if defibrillation is required in the presence of an ICD or permanent pacemaker, then paddles should be placed as far from the device as possible and in a perpendicular orientation to the device leads (e.g., anteroposterior, if possible) (57).
• A 2011 expert consensus statement from the Heart Rhythm Society and American Society of Anesthesiologists on the perioperative management of patients with pacemakers and defibrillators (63) and a practice advisory from the American Society of Anesthesiologists (64) reinforces these recommendations.

Rationale

• A permanent pacemaker or an ICD can malfunction in the presence of electrocautery.

Comments

• Placing a magnet over a pacemaker usually causes it to revert to asynchronous ventricular or dual chamber pacing; thus, its function is not affected by electrical interference. Once the magnet is removed, the pacemaker reverts to its programmed settings.
• Placing a magnet over a defibrillator usually temporarily suspends its programmed therapy options (including overdrive pacing and defibrillation), depending on the type of ICD and its programming. Once the magnet is removed, the ICD reverts to its previously programmed settings. Older defibrillators may not revert to active therapy; thus, ICDs should be interrogated after any magnet use. Magnet placement does not usually affect bradycardia (pacemaker) functions of the ICD.
• Electrocautery may damage electronic circuitry or programming of pacemakers and ICDs if performed in close proximity to the device generator, particularly if the device battery is at ‘electronic replacement indicator’ or ‘end of life.’

3.5 Do not place routine temporary transvenous pacemakers because of intraventricular conduction delays or bundle branch block patterns on preoperative ECG.

Recommendations

• Do not administer specific therapy for most preexisting conduction delays.

Evidence

• Studies have failed to show an increase in the perioperative incidence of new, high-grade heart block in patients with preoperative bifascicular block, with the possible exception of complete left bundle branch block (51; 52; 53; 61).

Rationale

• Unexpected heart block during the perioperative period is no more likely in patients with conduction delays compared with patients with normal conduction.

Comments

• A transvenous pacemaker should rarely be inserted prophylactically for the indication of conduction delay on the baseline ECG, although it should be readily available if a patient with a preexisting left bundle branch block undergoes surgery during which a pulmonary arterial catheter is placed (26).
3.6 Consider intraoperative interventions that reduce risk for arrhythmia in patients having open cardiac procedures.

Recommendations

- During open cardiac procedures, minimize mechanical and procedural risks for postoperative arrhythmias, and place temporary epicardial pacing wires.
- Use minimally invasive and off-pump techniques for CABG and valvular surgery whenever possible to reduce the risk for postoperative atrial arrhythmias.
- During cardiac bypass, use mild intraoperative hypothermia (34°C [93.2°F]).
- Consider left atrial appendage removal in patients at high risk for postoperative thromboembolic complications.

Evidence

- Epicardial lead placement allows for atrial overdrive pacing to suppress atrial fibrillation (81; 82), rapid atrial pacing to convert atrial flutter, efficient treatment of bradyarrhythmias, added diagnostic information in the management of new arrhythmias, and AV synchrony in the postoperative period.
- Intraoperative removal of the left atrial appendage has been advocated as a potential intervention to reduce postoperative stroke risk in patients at high risk to develop postoperative atrial fibrillation or in patients with known chronic atrial fibrillation (81; 82). Randomized, controlled trials have yet to be performed.
- A case series showed that the maze procedure, which is a series of surgical atriotomy incisions aimed at interrupting the propagation of atrial fibrillation, may be performed during open cardiac procedures (usually in patients with valvular disease and atrial fibrillation, which is difficult to control) (83).
- A randomized trial compared surgery with and without maze procedure in 35 patients undergoing mitral valve replacement. The maze group had lower rates of atrial fibrillation at hospital discharge (44% vs. 100%, P=0.002) and at 1 year (8% vs. 80%, P=0.007) (84).
- A retrospective cohort study found a trend towards a lower rate of postoperative atrial fibrillation in patients undergoing CABG without cardiopulmonary bypass or cardioplegia, compared with patients undergoing standard CABG (85).
- In a case series of 969 patients undergoing CABG without cardiopulmonary bypass (off-pump), 21% had postoperative atrial fibrillation. Minimally invasive direct CABG was associated with a lower incidence of atrial fibrillation (OR, 0.4 [CI, 0.3 to 0.7]; P<0.001) (86).
- A randomized trial compared off-pump with conventional (on-pump) CABG (n=100 in each group). There was a lower rate of postoperative atrial fibrillation in the patients undergoing off-pump CABG (11% vs. 45%; P<0.001). A multivariate analysis of the same data showed that cardiopulmonary bypass/cardioplegic arrest was the only independent predictor of atrial fibrillation (OR, 7.4 [CI, 3.4 to 17.9]) (87).
- A randomized trial compared mild (34°C [93.2°F]) and moderate (28°C [82.4°F]) intraoperative hypothermia in patients undergoing CABG. There were lower rates of postoperative atrial fibrillation in the mild hypothermia group (32).
- In a retrospective review of more than 3800 patients undergoing open cardiac surgical procedures, the following were all found to lead to a statistically significant risk for development of postoperative atrial fibrillation by univariate analysis: cardiac venting via the right superior pulmonary vein, the lack of use of topical ice slush, and inotropic agent use for >30 min after termination of bypass (88).
- A prospective observational study of predictors of atrial fibrillation after CABG found that longer cross-clamp time was a weak predictor of atrial fibrillation (adjusted OR, 1.06/15 min [CI, 1.0 to 1.11]) (89).
- A randomized trial of short-duration (2 min) aortic cross-clamping at the initial time of cardiac venting (‘ischemic preconditioning’) compared with control conditions in 85 patients undergoing
CABG found lower rates of atrial fibrillation in the ischemic preconditioning group (21.4% vs. 46.5%, \( P=0.015 \)) (90).

**Rationale**
- Intraoperative factors during open cardiac procedures can contribute to risk of postoperative tachyarrhythmias and bradyarrhythmias. Anticipation of postoperative complications can lead to preventive interventions in the intraoperative time period.

**Comments**
- Because postoperative tachyarrhythmias and conduction disease are common in patients undergoing open cardiac procedures (especially with valvular intervention), empirical placement of epicardial leads for overdrive pacing of tachyarrhythmias as well as bradycardic rhythms is now standard intraoperative protocol in most institutions.

### 3.7 Anticipate intraoperative reflex vagal stimulation as a common cause of bradycardia and conduction disorders, and be prepared to use atropine or temporary pacing as needed.

**Recommendations**
- Administer intravenous atropine if bradycardia and hypotension occur due to intraoperative reflex vagal stimulation.
- If intraoperative bradycardia and hypotension is unresponsive to atropine, treat with transcutaneous or transvenous temporary pacing.

**Evidence**
- Spinal or epidural anesthesia and laryngoscopy can provoke sinus node dysfunction from vagal stimulation, including pathologic sinus bradycardia and/or sinus arrest (91).
- Narcotics produce central vagal stimulation and subsequent bradycardia (92).
- Intraoperative bradyarrhythmias are seen commonly in ophthalmologic surgery and intra-abdominal surgery with mesenteric traction, usually secondary to activation of the vagus nerve reflex (26). Multiple anesthetic drugs (e.g., fentanyl, succinylcholine, and vecuronium) can increase the risk for operative bradyarrhythmias (93).
- Acetylcholinesterase given to antagonize neuromuscular blockade may cause bradycardia from the effects of acetylcholine on the heart (94).
- Interscalene block anesthesia can cause reflex bradycardia and hypotension, which is attributed to the Bezold-Jarisch reflex (25).
- In case reports, ophthalmologic atropine has initiated supraventricular tachyarrhythmias, and ophthalmologic timolol has been linked to bradycardia (95; 96).
- Spinal anesthesia, with inhibition of the cardiac-innervating preganglionic sympathetic fibers, may cause unopposed parasympathetic activity, and subsequent bradycardia, peripheral vasodilation, and hypotension (26).

**Rationale**
- Intraoperative reflex vagal stimulation can be induced by multiple mechanisms.
- Although vagal responses are usually not life threatening, intraoperative hypotension and bradycardia can usually be avoided with atropine administration to prevent secondary hemodynamic imbalances intraoperatively.

### 3.8 Consider biatrial pacing via epicardial leads to reduce the risk for postoperative atrial fibrillation after open cardiac surgery.

**Recommendations**
- In the absence of contraindications, consider atrial overdrive pacing via epicardial leads in patients at high risk for developing postoperative atrial fibrillation.
Evidence
- A 2013 Cochrane review of interventions to prevent postoperative atrial fibrillation in patients undergoing heart surgery included 118 studies with 17,364 participants. Several interventions reduced the rate of postoperative atrial fibrillation; β-blockers (OR, 0.33 [CI, 0.26 to 0.43]) and sotalol (OR, 0.34 [CI, 0.26 to 0.43]) were most efficacious, followed by amiodarone (OR, 0.43 [CI, 0.34 to 0.54]), magnesium (OR, 0.55 [CI, 0.41 to 0.73]), atrial pacing (OR, 0.47 [CI, 0.36 to 0.61]) and posterior pericardiotomy (OR, 0.35 [CI, 0.18 to 0.67]). The interventions did not significantly reduce length of stay or mortality (72).
- A 2003 meta-analysis of eight trials including over 700 patients undergoing open heart surgery showed a significant reduction in the incidence of postoperative atrial fibrillation in patients receiving biatrial overdrive pacing (OR, 2.6 [CI, 1.4 to 4.8]), right atrial overdrive pacing (OR, 2.5 [CI, 1.3 to 5.1]), or fixed high-rate biatrial pacing (OR, 1.8 [CI, 1.3 to 5.1]) (97).

Rationale
- The morbidity and mortality of postoperative atrial fibrillation is high, and prevention of onset may reduce in-hospital mortality and patient-related costs.

Comments
- Atrial pacing for the prevention of postoperative atrial fibrillation is a specialized situation requiring the expertise of an electrophysiologist, a cardiologist, or a cardiothoracic surgeon familiar with the use of pacemakers.

3.9 Consider postoperative telemetry monitoring for patients at risk for postoperative arrhythmia and conduction disorders. 

Recommendations
- Continue telemetry monitoring for at least 3 to 4 days after open cardiac surgery and 1 to 2 days after intermediate- and high-risk non-cardiac surgery.
- Do not use telemetry monitoring after low-risk non-cardiac surgery.
- See table Cardiac Risk of Non-cardiac Surgical Procedures.

Evidence
- Mainly consensus.
- Although >80% of patients may have transient postoperative arrhythmias on telemetry monitoring, <5% are of clinical importance (1).
- The peak incidence of atrial fibrillation is between postoperative days 2 and 4 (26).

Rationale
- Monitoring for new arrhythmias allows for prompt diagnosis and treatment.

3.10 Minimize the postoperative use of positive inotropic drugs. 

Recommendations
- Use positive inotropic drugs judiciously and only if they are expected to positively affect the final clinical outcome, recognizing that they can precipitate cardiac arrhythmias.

Evidence
- In an observational study of 131 patients who underwent CABG only, the occurrence of postoperative atrial fibrillation was significantly higher in patients who received positive inotropic drugs postoperatively. Atrial fibrillation occurred in 30% of patients who received positive inotropic drugs vs. 14% in those who did not. The use of positive inotropic drugs was an independent predictor of the occurrence of postoperative atrial fibrillation (44).
- In an observational study of 199 patients who underwent cardiac surgery including CABG and valve surgery, the occurrence of postoperative atrial fibrillation was significantly higher in patients who received positive inotropic drugs postoperatively. Atrial fibrillation occurred in 39% of patients who
received positive inotropic drugs vs. 14% in those who did not. The use of positive inotropic drugs was an independent predictor of the occurrence of postoperative atrial fibrillation. In addition, drugs with predominantly \( \beta \)-1-adrenergic receptor affinity were associated with a significantly higher incidence of postoperative atrial fibrillation. The incidence of postoperative atrial fibrillation was 44% with dopamine, 41% with dobutamine, and 20% with phenylephrine use (98).

Rationale

- Positive inotropic drugs, due to their myocardial excitability effect, may precipitate cardiac arrhythmia, especially postoperatively when patients are more prone to develop hypoxia, electrolyte imbalance, and acid-base disturbances.
- These drugs, due to their \( \beta \)-1-agonist activity, will negate the effect of \( \beta \)-blockers; the use of \( \beta \)-blockers has been proven to reduce the risk of postoperative cardiac arrhythmia.
4. Patient Education

Provide patients who are at high risk for arrhythmias with information about the types of and risks for arrhythmias, and discuss potential interventions, if appropriate, that could reduce their risk.

4.1 Inform patients of their perioperative arrhythmia risk and of recommendations to reduce this risk, including preoperative drug prophylaxis.

Recommendations

- Inform patients about the effectiveness of preoperative arrhythmia prophylaxis to improve medication compliance and adherence to therapy.
- Inform patients undergoing cardiac surgery about potential complicating bradyarrhythmias and tachyarrhythmias, and potential treatments they can expect (e.g., epicardial leads, new drugs).
- Educate patients postoperatively if they have clinically significant arrhythmias that require a change in therapy and outpatient follow-up with a specialist, and facilitate this follow-up.

Evidence

- Consensus

Rationale

- Patients may benefit from information about their arrhythmia risk, especially those at high risk, and they may be more compliant with suggested prophylactic antiarrhythmic drugs.
5. Follow-up

Recognize the potential complications that can arise as a result of perioperative arrhythmias, and arrange for appropriate therapies and consultation or follow-up with a specialist.

5.1 Document a new postoperative arrhythmia with telemetry strip monitoring and a 12-lead ECG, and investigate possible concomitant or exacerbating conditions.

**Recommendations**
- Obtain for a new postoperative arrhythmia:
  - Formal 12-lead ECG
  - Intracardiac electrogram tracing from epicardial pacing wires, if available
  - Telemetry strips of the arrhythmia onset and termination
- Evaluate the patient with a focused history and physical exam.
- Obtain documentation of left ventricular function, if available.
- Search for infectious, pulmonary, or electrolyte abnormalities, which may contribute to arrhythmogenesis.
- See table [Treatment and Outcomes of Newly Diagnosed Postoperative Arrhythmias](#).

**Evidence**
- The unique combination of postoperative factors, including electrolyte abnormalities, hypoxemia, cardiac ischemia, and catecholamine excess in the setting of occult or overt heart disease, provides a highly arrhythmogenic setting. Primary myocardial ischemia is rarely an initiator of most postoperative arrhythmias (26).

**Rationale**
- Appropriate and effective treatment of any arrhythmia hinges upon correct diagnosis.
- A secondary cause of arrhythmia should always be ruled out.

5.2 Treat specific postoperative arrhythmias in a diagnosis-specific manner.

**Recommendations**
- Treat newly diagnosed postoperative arrhythmias and conduction disturbances based on the specific disturbance as determined by ECG or telemetry monitoring.
- See table [Treatment and Outcomes of Newly Diagnosed Postoperative Arrhythmias](#).
- See module [Atrial Fibrillation](#).

**Evidence**
- Mainly consensus.

**Rationale**
- Appropriate and effective treatment of any arrhythmia is paramount to successful patient management.
References


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63. Crossley GH, Poole JE, Rozner MA, Asirvatham SJ, Cheng A, Chung MK, et al. The Heart Rhythm Society (HRS)/American Society of Anesthesiologists (ASA) Expert Consensus Statement on the perioperative management of patients with implantable defibrillators, pacemakers and arrhythmia monitors: facilities and patient management this document was developed as a joint project with the American Society of Anesthesiology (ASA), and in collaboration with the American Heart Association (AHA), and the Society of Thoracic Surgeons (STS). Heart Rhythm. 2011;8:1114-54. (PMID: 21722856)


Glossary

ACC
American College of Cardiology

AHA
American Heart Association

AV
atrioventricular

AVNRT
atrioventricular nodal reentrant tachycardia

AVRT
atrioventricular reentrant tachycardia

CABG
coronary artery bypass graft

CAD
coronary artery disease

CI
certainty interval

DCCV
direct current cardioversion

ECG
electrocardiogram, electrocardiography

EF
ejection fraction

GI
gastrointestinal

HF
heart failure

HR
hazard ratio

ICD
implantable cardioverter-defibrillator

ICU
intensive care unit

INR
international normalized ratio

LMWH
low-molecular-weight heparin

NSR
normal sinus rhythm

NSVT
nonsustained ventricular tachycardia

NYHA
New York Heart Association

OR
odds ratio
**RR**
risk ratio

**SVT**
supraventricular tachycardia
## Tables

### Cardiac Risk of Non-cardiac Surgical Procedures

<table>
<thead>
<tr>
<th>High Cardiac Risk &gt;5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergent major operations</td>
</tr>
<tr>
<td>Major vascular surgery</td>
</tr>
<tr>
<td>Peripheral vascular surgery</td>
</tr>
<tr>
<td>Prolonged surgical procedures</td>
</tr>
</tbody>
</table>

### Intermediate Cardiac Risk <5%

<table>
<thead>
<tr>
<th>Carotid endarterectomy</th>
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<tbody>
<tr>
<td>Head and neck surgery</td>
</tr>
<tr>
<td>Intraperitoneal and open thoracic surgery</td>
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<tr>
<td>Orthopedic surgery (in elderly)</td>
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<tr>
<td>Prostate surgery</td>
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</tbody>
</table>

### Low Cardiac Risk <1%

<table>
<thead>
<tr>
<th>Ophthalmologic procedures</th>
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<tbody>
<tr>
<td>Superficial procedures</td>
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<tr>
<td>Endoscopic procedures</td>
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<tr>
<td>Cataract surgery</td>
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<tr>
<td>Breast surgery</td>
</tr>
</tbody>
</table>

Adapted from ACC/AHA guidelines [57].
## Risk Stratification for Perioperative Thromboembolism

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Indication for Anticoagulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>High*</td>
<td>Mechanical Heart Valve</td>
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<tr>
<td></td>
<td>Prosthetic mitral valve</td>
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<tr>
<td></td>
<td>Any caged-ball or tilting disc prosthetic aortic valve</td>
</tr>
<tr>
<td></td>
<td>Recent (within 6 mo) stroke or transient ischemic attack</td>
</tr>
<tr>
<td></td>
<td>Atrial Fibrillation</td>
</tr>
<tr>
<td></td>
<td>CHADS&lt;sub&gt;2&lt;/sub&gt; score of 5 or 6</td>
</tr>
<tr>
<td></td>
<td>Stroke or TIA within 3 months</td>
</tr>
<tr>
<td></td>
<td>Rheumatic valvular heart disease</td>
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<tr>
<td></td>
<td>VTE within 3 months</td>
</tr>
<tr>
<td></td>
<td>Known severe thrombophilia (e.g., protein S or C deficiency, ACA, antiphospholipid syndrome)</td>
</tr>
<tr>
<td>High</td>
<td>Mechanical Heart Valve</td>
</tr>
<tr>
<td></td>
<td>Prosthetic mitral valve</td>
</tr>
<tr>
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<td>Any caged-ball or tilting disc prosthetic aortic valve</td>
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<tr>
<td></td>
<td>Atrial Fibrillation</td>
</tr>
<tr>
<td></td>
<td>CHADS&lt;sub&gt;2&lt;/sub&gt; score of 5 or 6</td>
</tr>
<tr>
<td></td>
<td>Stroke or TIA within 3 months</td>
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<tr>
<td></td>
<td>Rheumatic valvular heart disease</td>
</tr>
<tr>
<td></td>
<td>VTE within 3 months</td>
</tr>
<tr>
<td></td>
<td>Known severe thrombophilia (e.g., protein S or C deficiency, ACA, antiphospholipid syndrome)</td>
</tr>
<tr>
<td>Moderate</td>
<td>Bileaflet prosthetic aortic valve and one or more of the following: atrial fibrillation, prior stroke or TIA, hypertension, diabetes, HF, age &gt;75 y</td>
</tr>
<tr>
<td></td>
<td>CHADS&lt;sub&gt;2&lt;/sub&gt; score of 3 or 4</td>
</tr>
<tr>
<td></td>
<td>VTE within the past 3-12 mo</td>
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<tr>
<td></td>
<td>Non-severe thrombophilia (e.g., heterozygous factor V Leiden or prothrombin gene</td>
</tr>
<tr>
<td></td>
<td>Recurrent VTE</td>
</tr>
<tr>
<td></td>
<td>Active cancer (treated within 6 mo or palliative)</td>
</tr>
<tr>
<td>Low</td>
<td>Bileaflet aortic valve prosthesis without atrial fibrillation and no other risk factors for stroke</td>
</tr>
<tr>
<td></td>
<td>CHADS&lt;sub&gt;2&lt;/sub&gt; score of 0 to 2 (assuming no prior stroke or transient ischemic attack)</td>
</tr>
<tr>
<td></td>
<td>VTE &gt;12 mo previous and no other risk factors</td>
</tr>
</tbody>
</table>

ACA = anticardiolipin antibody; CHADS<sub>2</sub> factors: hypertension, age ≥ 75 years, diabetes mellitus, and stroke or transient ischemic attack; HF = heart failure; VTE = venous thromboembolism

Adapted from: 65.
### Treatment and Outcomes of Newly Diagnosed Postoperative Arrhythmias

<table>
<thead>
<tr>
<th>Arrhythmia</th>
<th>Specific Recommendations</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrial/ventricular ectopy</td>
<td>Rule out electrolyte abnormalities&lt;br&gt;No treatment indicated</td>
<td>May increase risk of subsequent sustained atrial and ventricular arrhythmias (33; 35)&lt;br&gt;Does not increase risk for myocardial infarction or death (35; 99)</td>
</tr>
<tr>
<td>Sinus tachycardia</td>
<td>Rule out pain, anxiety, hypovolemia, infection, hypoxia, hypercarbia, alcohol withdrawal, HF (26)&lt;br&gt;Rate control rarely indicated&lt;br&gt;If complications of tachycardia are suspected (e.g., HF secondary to diastolic dysfunction), iv diltiazem or metoprolol may be given</td>
<td>Atrial fibrillation increases risk of embolic cerebrovascular accidents, hypotension, and pulmonary edema (31; 88; 113)&lt;br&gt;Spontaneous conversion rates in hospital are 15%-30% after open cardiac surgery (102; 107; 108)&lt;br&gt;All antiarrhythmic drugs are associated with proarrhythmic effects and are most pronounced in the elderly, patients with a history of myocardial infarction, and patients with impaired left ventricular function (102; 114)&lt;br&gt;Spontaneous conversion rates at 1 month after open cardiac surgery approach 90% (115; 116)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>Initially rate control with β-blockers or calcium-channel blockers (100); give digoxin if relative hypotension prevents use of these drugs&lt;br&gt;Anticoagulate with heparin, low-molecular weight heparin, or direct thrombin inhibitors, followed by warfarin if atrial fibrillation lasts &gt;48 hrs, and if surgical bleeding risk is acceptable (101)&lt;br&gt;Cardiovert if hemodynamic instability, severe symptoms, or contraindications to anticoagulation (102)&lt;br&gt;Biphasic defibrillators should be used if available; they achieve successful cardioversion with less energy (103)&lt;br&gt;Consider drug conversion with amiodarone; it is successful in 50%-90% of cases (104; 105; 106)&lt;br&gt;Consider ibutilide (conversion rate 30%-40%), disopyramide, or propafenone in the conversion of postcardiac surgery atrial fibrillation (107; 108; 109; 110)&lt;br&gt;Consider ibutilide pretreatment before electrical cardioversion (111)&lt;br&gt;Continue antiarrhythmic drugs for 4-6 weeks in patients with persisting or recurrent atrial fibrillation (102)&lt;br&gt;Follow patients on antiarrhythmic drugs after discharge to monitor QT interval and sinus rate. One simple way to follow is with daily asymptomatic recordings from a continuous-loop event recorder (112)</td>
<td>Atrial fibrillation increases risk of embolic cerebrovascular accidents, hypotension, and pulmonary edema (31; 88; 113)&lt;br&gt;Spontaneous conversion rates in hospital are 15%-30% after open cardiac surgery (102; 107; 108)&lt;br&gt;All antiarrhythmic drugs are associated with proarrhythmic effects and are most pronounced in the elderly, patients with a history of myocardial infarction, and patients with impaired left ventricular function (102; 114)&lt;br&gt;Spontaneous conversion rates at 1 month after open cardiac surgery approach 90% (115; 116)</td>
</tr>
<tr>
<td>Atrial flutter</td>
<td>Treat initially with rate control, as with atrial fibrillation&lt;br&gt;Anticoagulate if no conversion to NSR in 48 hours, if surgically acceptable bleeding risk&lt;br&gt;Attempt atrial overdrive pacing with epicardial leads, if present, to convert to NSR. Concomitant ibutilide or procainamide may enhance efficacy (117)&lt;br&gt;Cardiovert if hemodynamic instability, severe symptoms, or contraindications to anticoagulation&lt;br&gt;Give ibutilide, 1 mg iv, for drug cardioversion (up to 78% conversion rate) (107; 118)&lt;br&gt;If atrial flutter is refractory to medical control or persists in the extended postoperative state, consider radiofrequency ablation</td>
<td>Rate control of atrial flutter is often more difficult than atrial fibrillation. Early DCCV may be required&lt;br&gt;47%-78% conversion rates of postcardiac surgery atrial flutter have been observed with ibutilide (107; 118)&lt;br&gt;Atrial overdrive pacing terminates up to 95% of postoperative atrial flutter (122)</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>Management</td>
<td></td>
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<td>-----------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
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<tr>
<td><strong>Reentrant supraventricular arrhythmias:</strong></td>
<td>Treat these regular narrow complex tachycardias initially with vagal maneuvers (carotid sinus massage), followed by adenosine, β-blockers, or calcium-channel blockers (123) Perform DCCV if hemodynamically unstable Initiate long-term standing dose β-blockers or calcium-channel blockers if recurrent arrhythmia Consider electrophysiology study and ablation if recurrent or uncontrolled (usually not performed in the immediate postoperative state) (124)</td>
<td></td>
</tr>
<tr>
<td>AV nodal reentrant tachycardia, and AV reentrant tachycardia</td>
<td></td>
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</tr>
<tr>
<td><strong>Multifocal atrial tachycardia</strong></td>
<td>Search for underlying pulmonary complications Rate control with β-blocking or calcium-channel blocking drugs (125) Consider suppressing arrhythmia with amiodarone (126) DCCV ineffective</td>
<td></td>
</tr>
<tr>
<td><strong>Ectopic atrial tachycardia</strong></td>
<td>Search for underlying pulmonary complications or digitalis intoxication Atrial tachycardias associated with AV block (e.g., 2:1 AV block) are suggestive of digitalis intoxication Rate control with β-blocking or calcium-channel blocking drugs (125) Consider suppressing arrhythmia with amiodarone (126) DCCV may be attempted, although only case reports have been published (127) Recurrences in the postoperative state are not uncommon</td>
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<tr>
<td><strong>Nonsustained ventricular tachycardia</strong></td>
<td>Rule out secondary causes, such as electrolyte abnormalities or myocardial ischemia (26) Give β-blocking drugs to reduce episodes of NSVT No specific therapy is indicated for patients with hemodynamically insignificant NSVT (26) Amiodarone, procainamide, or lidocaine may be given for symptomatic or hemodynamically significant NSVT; however, no data exist regarding the outcome of short-term postoperative therapy with these drugs (26) Consider electrophysiology study, with implantable cardioverter-defibrillator placement if positive, if NSVT is recognized &gt;4 days after open cardiac surgery in any patient with coronary artery disease and an ejection fraction &lt;40% (129; 130)</td>
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<tr>
<td><strong>Sustained wide complex tachycardias</strong></td>
<td>Consider all wide complex tachycardias to be ventricular in origin, in absence of convincing evidence to the contrary Obtain a 12-lead ECG in all hemodynamically tolerated, wide complex tachycardias (131; 132). If available, tracings from epicardial wires should be recorded to aid in diagnosis Perform DCCV in all hemodynamically unstable, wide complex tachycardias; use biphasic defibrillators if available, because they 90% of wide complex tachycardias in patients with coronary artery disease are ventricular in origin (136)</td>
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<tr>
<td><strong>Postoperative atrial tachycardias</strong></td>
<td>Postoperative atrial tachycardias are often transient, related to the acute post-operative metabolic state (128) Recurrent atrial tachycardias may be amenable to catheter ablation, in the extended postoperative state (128)</td>
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</tbody>
</table>
### Perioperative Management of Rhythm and Conduction Disorders

<table>
<thead>
<tr>
<th>Condition</th>
<th>Management</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinus node dysfunction, AV Wenckebach, and junctional rhythms</td>
<td>Do not give specific therapy if hemodynamically stable</td>
<td>Little or no impact on overall prognosis</td>
</tr>
<tr>
<td>New left or right bundle-branch block</td>
<td>Rule out occult myocardial ischemia with serial enzymes and ECG</td>
<td>New left bundle-branch block may be a marker of myocardial damage, and it has been associated with worse outcomes in some studies</td>
</tr>
<tr>
<td>High-grade or complete heart block</td>
<td>Discontinue negative chronotropic (rate-slowing) drugs</td>
<td>Initial observation with a temporary ventricular pacing wire is appropriate; a permanent pacemaker is indicated if heart block persists for 7-14 days postoperatively</td>
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<td></td>
<td>Give iv atropine</td>
<td>Retrospective data suggest that patients with heart block persisting for &gt;48 hrs after valvular surgery are unlikely to recover, and early pacemaker implantation may be considered</td>
</tr>
</tbody>
</table>

AV = atrioventricular; CABG = coronary artery bypass graft; DCCV = direct current cardioversion; ECG = electrocardiogram; HF = heart failure; iv = intravenous; NSR = normal sinus rhythm; NSVT = nonsustained ventricular tachycardia.
Figures

Optimal Placement of Defibrillator Pads for Direct Current Cardioversion of Atrial Fibrillation