Guidelines for Perioperative Cardiovascular Evaluation and Management for Noncardiac Surgery (JCS 2008)

– Digest Version –

JCS Joint Working Group

Table of Contents

Introduction to the Revised Guidelines .......................... 989
I Outline .................................................................. 990
1. Outline of Diagnosis and Evaluation ............... 990
2. Outline of General Management .................. 992
3. Pregnancy/Delivery and Heart Disease .......... 994
II Descriptions ......................................................... 996
1. Ischemic Heart Disease ................................. 996
2. Valvular Heart Disease ............................ 998
3. Treatment of Congenital Heart Disease Before Corrective Surgery .................. 999
4. Adults With Congenital Heart Disease .......... 1000
5. Aortic Diseases .................................................. 1001
6. Peripheral Arterial Disease
   (Abdomen, Neck, and Lower Extremities) ........ 1003
7. Pulmonary Artery Disease ................... 1004
8. Idiopathic Cardiomyopathy ..................... 1005
9. Arrhythmias ..................................................... 1005
References ........................................................ 1007

(Circ J 2011; 75: 989–1009)

Introduction to the Revised Guidelines

As the population ages, more elderly patients are undergoing surgery. An increasing number of patients with heart disease are undergoing noncardiac surgery, and guidelines for perioperative cardiovascular evaluation and management for patients undergoing noncardiac surgery have become necessary. The Committee on Preparation for “the Guidelines for Perioperative Cardiovascular Evaluation and Management for Noncardiac Surgery”, which was established in 2001 at the request of the Scientific Committee of the Japanese Circulation Society, published the first edition of the guidelines in 2002.

While the ACC/AHA Guidelines for Perioperative Cardiovascular Evaluation for Noncardiac Surgery highlighted the perioperative management of patients with ischemic heart disease, our guidelines were intended to comprehensively describe ischemic heart disease and other common heart diseases which physicians often encounter during noncardiac surgery, and include risk management during pregnancy and delivery. In the present guidelines, the evidence and general agreement on the efficacy of diagnostic and treatment procedures are classified into Class I to III to help practitioners use the guidelines efficiently.

Class I: Conditions for which there is evidence for and/or general agreement that the procedure/treatment is useful.

Class II: Conditions for which there is conflicting evidence regarding the usefulness of a procedure/treatment.

Class IIa: Weight of opinion is in favor of usefulness.

Class IIb: Usefulness is less well established by evidence.

Class III: Conditions for which there is evidence and general agreement that a procedure/treatment is not useful.

Five years have passed since the release of the first edition of the guidelines, during which time surgical treatment has become more common among elderly patients and the diagnostic and treatment techniques for heart disease have further advanced. The guidelines were thus revised to reflect these changes.

In the present edition, we added to and substantially revised the descriptions about the role of percutaneous coronary intervention (PCI), focusing on drug eluting stents (DES), and aortic stent grafts during the treatment of patients undergoing noncardiac surgery. The descriptions of other cardiovascular diseases were also revised to reflect new findings.
However, it is quite difficult to conduct prospective randomized clinical studies in patients undergoing surgery, who are often in critical condition, and the data from such studies are also limited in many countries. Please note that the data obtained in this area of study described in the present guidelines may include many biases, as in the case of the first edition.

I Outline

1. Outline of Diagnosis and Evaluation

In order to determine treatment strategies of noncardiac surgery and obtain information necessary to ensure safe surgery, history taking and physical examination should be performed to identify patients in whom the risk for cardiovascular complications is high, and diagnosis and evaluation should then be performed. Physicians should at this point also consider the long-term risk of cardiovascular disease as well. In general, the risk for cardiac complications is high among patients with a marked decrease in exercise capacity (≤ 4 metabolic equivalents [METs]), and careful evaluation of such patients is often necessary.

(1) Risk Classification

The risk factors for cardiac complications during the perioperative period are classified as shown in Table 1. Patients with major risk factors require intensive care during the perioperative period. In some cases, non-urgent noncardiac surgery must be postponed or cancelled in patients with major risk factors. Systems to predict the incidence of cardiac complications by scoring of relevant factors such as the Cardiac Risk Index System (CRIS) in Table 2 have been proposed.

(2) Preoperative Evaluation

In principle, preoperative cardiovascular evaluation should be performed using noninvasive techniques. However, Holter ECG and echocardiography are not useful in evaluating the risk of perioperative myocardial infarction. Appropriate techniques must be used, even if they are invasive. In addition, there is little pathological significance to a slight increase in cardiothoracic ratio that results from horizontal position of the heart due to obesity or other causes, or a single supraventricular extrasystole, ectopic sinus rhythm, atrial fibrillation, a single unifocal ventricular extrasystole, or first degree atrioventricular block in patients with excellent exercise capacity. Unnecessary examinations should be avoided. Since the incidence of serious complications of invasive examinations such as cardiac catheterization and cervical angiography is about 1%, such examinations must be reserved for patients in whom the results of examination will significantly contribute to the improvement of prognosis and results of noncardiac surgery. Table 3 lists the criteria for indication of preoperative diagnostic evaluation.

Table 1. Risk Factors for Cardiac Complications During the Perioperative Period of Noncardiac Surgery

<table>
<thead>
<tr>
<th>1) Major risk factors</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unstable coronary artery disease</td>
<td>5</td>
</tr>
<tr>
<td>Myocardial infarction occurring 7 to 30 days before surgery with clinical signs/symptoms and laboratory findings of myocardial ischemia detectable on noninvasive examinations, unstable angina, or severe angina (Canadian Class III or IV angina)</td>
<td>5</td>
</tr>
<tr>
<td>Decompensated congestive heart failure</td>
<td>5</td>
</tr>
<tr>
<td>Severe arrhythmias</td>
<td>5</td>
</tr>
<tr>
<td>Advanced atrioventricular block</td>
<td>5</td>
</tr>
<tr>
<td>Symptomatic ventricular arrhythmia</td>
<td>5</td>
</tr>
<tr>
<td>Supraventricular arrhythmia associated with abnormal ventricular rates</td>
<td>5</td>
</tr>
<tr>
<td>Severe valvular disease</td>
<td>5</td>
</tr>
<tr>
<td>2) Intermediate risk factors</td>
<td></td>
</tr>
<tr>
<td>Mild angina (Canadian Class I or II angina)</td>
<td></td>
</tr>
<tr>
<td>History of myocardial infarction with abnormal Q waves</td>
<td></td>
</tr>
<tr>
<td>History of compensated congestive heart failure or congestive heart failure</td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td></td>
</tr>
<tr>
<td>Renal failure</td>
<td></td>
</tr>
<tr>
<td>3) Mild risk factors</td>
<td></td>
</tr>
<tr>
<td>Advanced age</td>
<td></td>
</tr>
<tr>
<td>Abnormal ECG (left ventricular hypertrophy, left bundle branch block, ST-T abnormalities)</td>
<td></td>
</tr>
<tr>
<td>Rhythm other than sinus</td>
<td></td>
</tr>
<tr>
<td>Decrease in cardiac functional capacity (decrease in exercise capacity)</td>
<td></td>
</tr>
<tr>
<td>History of stroke</td>
<td></td>
</tr>
<tr>
<td>Poorly-controlled hypertension</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Cardiac Risk Index System (CRIS)

<table>
<thead>
<tr>
<th></th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>History</td>
<td></td>
</tr>
<tr>
<td>Age &gt;70 years</td>
<td>5</td>
</tr>
<tr>
<td>Myocardial infarction in previous 6 months</td>
<td>10</td>
</tr>
<tr>
<td>Aortic stenosis</td>
<td>3</td>
</tr>
<tr>
<td>Physical examination</td>
<td></td>
</tr>
<tr>
<td>S3 gallop, jugular venous distention, or congestive heart failure</td>
<td>11</td>
</tr>
<tr>
<td>ECG</td>
<td></td>
</tr>
<tr>
<td>Rhythm other than sinus</td>
<td>7</td>
</tr>
<tr>
<td>&gt;5 PVC/min</td>
<td>7</td>
</tr>
<tr>
<td>General status and laboratory findings</td>
<td></td>
</tr>
<tr>
<td>PaO2 &lt; 60 mmHg</td>
<td>3</td>
</tr>
<tr>
<td>PaCO2 &gt; 50 mmHg</td>
<td>3</td>
</tr>
<tr>
<td>Potassium &lt; 3 mEq/L</td>
<td>3</td>
</tr>
<tr>
<td>BUN &gt; 50 mg/dL</td>
<td>3</td>
</tr>
<tr>
<td>Creatinine &gt; 3 mg/dL</td>
<td>3</td>
</tr>
<tr>
<td>Bedridden</td>
<td>3</td>
</tr>
<tr>
<td>Surgery</td>
<td></td>
</tr>
<tr>
<td>Emergency</td>
<td>4</td>
</tr>
<tr>
<td>Intra-thoracic</td>
<td>3</td>
</tr>
<tr>
<td>Intra-abdominal</td>
<td>3</td>
</tr>
<tr>
<td>Aortic</td>
<td>3</td>
</tr>
</tbody>
</table>

Incidence of cardiac complications: Class I (0 to 5 points): 1%; Class II (6 to 12 points): 5%; Class III (13 to 25 points): 11%; Class IV (≥ 26 points): 22%

PVC, premature ventricular contraction; PaO2, partial pressure of arterial oxygen; PaCO2, partial pressure of arterial carbon dioxide; BUN, blood urea nitrogen.

Adapted from N Engl J Med 1977; 297: 845–850, with permission from Massachusetts Medical Society.
ative coronary angiography. It is expected that innovative techniques such as multislice computed tomography (CT) will change diagnostic strategies in the near future.

It should be noted that stress ECG, stress myocardial perfusion imaging, and other techniques commonly considered noninvasive procedures may occasionally cause even death when significant stenosis of the left main coronary trunk or severe aortic valve stenosis is present.

(3) Perioperative Monitoring
Although it is important to promptly detect perioperative cardiac complications in patients undergoing noncardiac surgery, appropriate monitoring should be performed in selected patients in whom cardiac complications are likely to occur for appropriate period of time. Excessive use of invasive monitoring must be avoided. Esophageal stethoscopes, peripheral temperature and percutaneous oxygen saturation monitoring are not specific for cardiac complication.

i) ECG
ECG monitoring is best performed for patients with arrhythmia or coronary artery disease. Although postoperative myocardial ischemia is a strong predictive factor for perioperative cardiac complications, angina is missing in many cases. Once perioperative myocardial infarction occurs, 30 to 50% of patients will die, and long-term survival rate will be decreased. ST-segment monitoring is of diagnostic and therapeutic value. It is preferable that ECG monitoring should be continued until preoperative drug regimens for cardiac complications have been completely resumed. ECG monitoring before, during, immediately after surgery, and succeeding 2 days is a cost-effective strategy.

Arrhythmias during the early postoperative period are often caused by factors other than problems of the heart. Since supraventricular arrhythmia often disappears spontaneously and heart rhythm returns to sinus rhythm after causal factors have been eliminated, cardioversion is not recommended as a routine procedure for patients with it.

ii) Blood Pressure
Patients at risk for abrupt hemodynamic changes during noncardiac surgery should be continuously monitored for blood pressure using an arterial line. Although blood pressure, when used as a single measure, does not accurately reflect hemodynamic condition and cardiovascular events, continuous blood pressure monitoring during a limited period of time is indicated for certain types of patients such as those at high risk of perioperative myocardial infarction.

iii) Central Venous Line, Pulmonary Artery (Swan-Ganz) Catheter
A central venous line is inserted and placed in patients whom significant hemodynamic changes can occur during the perioperative period for inotropic support and rapid fluid administration. However, central venous pressure provides limited information about hemodynamic conditions. Monitoring using a pulmonary artery catheter may enable detailed evaluation of hemodynamics in high-risk patients, though there are problems associated with its insertion and placement.

iv) Transesophageal Echocardiography
Although transesophageal echocardiography gives important informations in patients whom monitoring of blood pressures and cardiac output is not sufficient, its usefulness in patients

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Table 3. Guidelines for Coronary Angiography

<table>
<thead>
<tr>
<th>Class I</th>
<th>Evidence for high risk of adverse outcome based on noninvasive test results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Angina unresponsive to adequate medical therapy</td>
</tr>
<tr>
<td></td>
<td>Unstable angina</td>
</tr>
<tr>
<td></td>
<td>Equivocal noninvasive test results in patients at high clinical risk and undergoing high-risk surgery</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class III</th>
<th>Low-risk noncardiac surgery with known coronary artery disease and no high-risk results on noninvasive testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>For screening of patients not undergoing appropriate noninvasive testing</td>
</tr>
<tr>
<td></td>
<td>Asymptomatic after coronary revascularization with excellent exercise capacity</td>
</tr>
<tr>
<td></td>
<td>Mild stable angina with good left ventricular function and no high-risk noninvasive test results</td>
</tr>
<tr>
<td></td>
<td>Noncandidate for coronary revascularization owing to concomitant medical illness, or severe left ventricular dysfunction</td>
</tr>
<tr>
<td></td>
<td>Undergoing adequate coronary angiography within 5 years</td>
</tr>
<tr>
<td></td>
<td>Refusal to consider coronary revascularization</td>
</tr>
</tbody>
</table>

Adapted from J Am Coll Cardiol 2002; 39: 542–553, with permission from Elsevier Inc. *Added to this table.

Table 4. Recommendations Regarding PCI and Patient Management Prior to Noncardiac Surgery

1. Dual antiplatelet therapy using aspirin and thienopyridine (ticlopidine or clopidogrel) is the most beneficial regimen for preventing in-stent thrombosis. It is recommended that, following stenting, especially using DES, patients undergo dual antiplatelet therapy for 12 months. Early discontinuation of this regimen significantly increases the risks of in-stent thrombosis, myocardial infarction, and death.

2. Physicians should be aware that dual antiplatelet therapy is required after stenting, and consider avoidance of DES implantation in patients who cannot complete 12-months thienopyridine therapy. Physicians should well consider whether to use DES or not in patients who have or are suspected to have malignant disease.

3. For patients who are to undergo PCI and who may require invasive procedures or surgery within 12 months after PCI, physicians should consider use of bare metal stents or balloon angioplasty rather than DES implantation.

4. Physicians should fully explain to patients the importance of antiplatelet therapy with thienopyridine, and instruct them to consult a physician when they need to discontinue antiplatelet therapy.

5. When invasive procedures are performed in patients with stents on antiplatelet therapy, physicians should be aware that early discontinuation of antiplatelet therapy after stenting may have serious complications, and should carefully discuss with cardiologists over the optimal treatment strategy.

6. It is preferable that elective surgery with a high risk of bleeding during and after surgery be avoided during the 12-months period after implantation of DES and at least one month after implantation of bare metal stents.

7. When patients with DES must discontinue thienopyridine therapy for surgical procedures, they should continue aspirin therapy whenever possible, and should resume thienopyridine therapy promptly after surgery. When all antiplatelet agents must be discontinued, it is preferable that patients be treated with heparin. However, there is no evidence of prevention of in-stent thrombosis by heparin therapy in patients receiving DES or bare metal stents, and heparin therapy is empirically conducted in many institutions in Japan.
Adapted from J Am Coll Cardiol 2006; 47: 2343–2355.19 with permission from Elsevier Inc.

2. Outline of General Management

(1) Preoperative Management
Although the most common strategy for improving cardiac condition before noncardiac surgery is drug treatment, preoperative intensive care or cardiac surgery may be performed before noncardiac surgery. Generally, preoperative medication for cardiovascular disease should be continued during and after surgery.

i) Cardiac Surgery Before Noncardiac Surgery
There is much debate concerning whether PCI and coronary artery bypass grafting (CABG) prior to noncardiac surgery can improve the short- and long-term prognosis of patients. It is preferable that such cardiac procedures be performed only in patients who meet the criteria provided in the ACC/AHA Guidelines. However, there is much confusion in the clinical setting regarding the indication of PCI, which have recently been advanced. We therefore provide guidelines for the indication of PCI in patients undergoing noncardiac surgery to ensure best practice in the current healthcare environment in Japan (Table 4).18

Since symptomatic valvular stenosis is often related to perioperative severe heart failure, patients with valvular stenosis often require balloon valvotomy or valve replacement prior to noncardiac surgery. Since patients with valvular regurgitation often maintain stable hemodynamics during the perioperative period, noncardiac surgery may be prioritized in this patient population. However, it is difficult to maintain hemo-

### Table 5. Guidelines for Use of β Blockers During the Perioperative Period of Noncardiac Surgery

<table>
<thead>
<tr>
<th>Class</th>
<th>β blockers should be continued in patients undergoing surgery who are receiving β blockers to treat angina, symptomatic arrhythmias, hypertension, or other indications.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>β blockers should be given to patients undergoing vascular surgery at high cardiac risk owing to the finding of ischemia on preoperative testing.</td>
</tr>
<tr>
<td>Class IIa</td>
<td>β blockers are probably recommended for patients undergoing vascular surgery in whom preoperative assessment identifies coronary heart disease.</td>
</tr>
<tr>
<td>Class III</td>
<td>β blockers are probably recommended for patients in whom preoperative assessment for vascular surgery identifies high cardiac risk as defined by the presence of multiple clinical risk factors.</td>
</tr>
</tbody>
</table>

### Table 6. Guidelines for the Prevention of Venous Thromboembolism During the Perioperative Period of Noncardiac Surgery

<table>
<thead>
<tr>
<th>Patient condition and surgical techniques</th>
<th>Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor surgery in patients &lt;40 years of age with no risk factors*</td>
<td>Early ambulation</td>
</tr>
<tr>
<td>Moderate-risk surgery in patients ≥40 years of age with no risk factors</td>
<td>ES, LDH (2 hours preoperatively and every 12 hours after), or IPC of the lower extremities</td>
</tr>
<tr>
<td>Major surgery in patients ≥40 years of age with risk factors</td>
<td>LDH (every 8 hours) or LMWH, IPC of the lower extremities if prone to wound bleeding.</td>
</tr>
<tr>
<td>Very high-risk surgery in patients ≥40 years of age with risk factors</td>
<td>LDH, LMWH, or dextran combined with IPC of the lower extremities.</td>
</tr>
<tr>
<td>Total hip replacement</td>
<td>LMWH (postoperative, subcutaneous, twice daily, fixed dose unmonitored) or warfarin (INR 2.0 to 3.0, started preoperatively or immediately after surgery), or adjusted dose unfractionated heparin (started preoperatively), ES or IPC may provide additional efficacy.</td>
</tr>
<tr>
<td>Total knee replacement</td>
<td>LMWH (postoperative, subcutaneous, twice daily, fixed dose unmonitored) or IPC of the lower extremities.</td>
</tr>
<tr>
<td>Hip fracture surgery</td>
<td>LMWH (preoperative, subcutaneous, fixed dose unmonitored) or warfarin (INR 2.0 to 3.0). IPC of the lower extremities may provide additional benefit.</td>
</tr>
<tr>
<td>Intracranial neurosurgery</td>
<td>IPC of the lower extremities with or without ES. Consider addition of LDH in high-risk patients.</td>
</tr>
<tr>
<td>Acute spinal cord injury with lower extremity paralysis</td>
<td>Adjusted dose heparin or LMWH for prophylaxis. Warfarin may also be effective. LDH, ES, and IPC of the lower extremities may have benefit when used together.</td>
</tr>
<tr>
<td>Patients with multiple trauma</td>
<td>IPC of the lower extremities, warfarin, or LMWH when feasible, serial surveillance with duplex ultrasonography may be useful. In selected very high-risk patients, consider prophylactic inferior vena cava filter.</td>
</tr>
</tbody>
</table>

*Risk factors for venous thromboembolism: Advanced age, prolonged bed rest or paralysis, history of venous thromboembolism, malignant tumor, major surgery of the abdomen, pelvis, or lower extremities, obesity, varicose veins, congestive heart failure, myocardial infarction, stroke, fractures in the abdomen, pelvis, or lower extremities, hypercoagulability, and high-dose estrogen therapy. ES, graded compression elastic stockings; LDH, low-dose subcutaneous heparin; IPC, intermittent pneumatic compression; LMWH, low molecular weight heparin; INR, international normalized ratio. Adapted from J Am Coll Cardiol 1996; 27: 910–948.17 with permission from Elsevier Inc.
dynamics in patients with left ventricular dysfunction.

ii) Hypertension
Untreated or poorly controlled hypertension (diastolic blood pressure $\geq 110$ mmHg) should be controlled prior to noncardiac surgery, preferably with $\beta$-blockers, which have been suggested to decrease the incidence of perioperative myocardial infarction. Perioperative treatment with $\beta$-blockers may decrease the incidence of cardiovascular complications of noncardiac surgery not only in patients with hypertension but also in those with heart disease or at high risk of perioperative cardiac events (Table 5).$^{19}$ Patients with hypertension before surgery are prone to be hypertensive during surgery,$^{19,20}$ and should be carefully managed to avoid perioperative heart/renal complications.

iii) Heart Failure
The presence of dilated or hypertrophic cardiomyopathy is closely associated with perioperative heart failure. Such patients need close evaluation of hemodynamic condition before noncardiac surgery and medical therapy to be eligible for noncardiac surgery, and must undergo intensive care and close monitoring after surgery. Patients with chronic decompensated heart failure, in particular, may benefit from invasive monitoring and intensive care. When noncardiac surgery is indicated children with congenital heart disease and heart failure, they should be treated with digoxis, diuretics, and water restriction to control heart failure before surgery. Some children require treatment with catecholamines and vasodilators.

iv) Venous Thromboembolism
Table 6 shows the guidelines for prevention of venous thromboembolism during the perioperative period of noncardiac surgery.$^{21}$

v) Patients After Cardiac Surgery
The risk of perioperative ischemia or reinfarction is expected to be low in patients following coronary revascularization when they are asymptomatic. However, patients with residual ischemia after coronary revascularization require careful management in a manner similar to that for patients with coronary disease.

It is important to adjust anticoagulation therapy in patients who have undergone mechanical valve replacement. Since the incidence of thrombosis is higher in mitral prosthesis than in aortic prosthesis, patients with mitral prosthesis should be managed more carefully.

The risk of perioperative cardiac complications is generally low among patients who have undergone corrective surgery for congenital heart disease. However, patients should be carefully evaluated for remaining defects. Since patients who have undergone palliative surgery only still have congenital heart disease, careful management is required.

Warfarin therapy should be discontinued one week prior to such surgery if possible, or 2 days prior to the surgery at the latest. Warfarin should be replaced with heparin in patients at high risk of thromboembolism. Vitamin K is sometimes used to antagonize the effects of warfarin prior to emergency surgery. Physicians should be aware that complete normalization of coagulation activity may occur in many cases. High-risk patients such as those with mechanical valves should resume anticoagulation therapy following noncardiac surgery as soon as the risk of bleeding has disappeared.

vi) Malignant Tumors and Cardiac Surgery
When cardiac surgery is performed in patients with malignant tumor, extracorporeal circulation during cardiac surgery may decrease immune function and disseminate cancer cells into the circulation. In patients with ischemic heart disease, such problems may be minimized by selecting off-pump coronary bypass surgery.

(2) Management of Anesthesia and Peri- and Postoperative Management

i) Selection of the Methods and Agents of Anesthesia
There are no particular anesthetic methods that yield significant myocardial protection during surgery. The most important prognostic factors are complications and surgical techniques. Although local anesthesia combined with intravenous anesthesia and/or analgesics was previously considered safe, a report pointed out that 30-day mortality was highest for it among the anesthetic methods evaluated.$^{22}$ Epidural anesthesia and spinal anesthesia are used in some cases, but may not be indicated for patients receiving anticoagulants and those with poor cardiac function. The effects of narcotics on the cardiovascular system are stable, but respiratory depression may occur. All volatile anesthetics may affect the cardiovascular system through a decrease in cardiac contractile force and decrease of afterload. When volatile anesthetics are administered to patients with heart diseases, hemodynamics should be monitored very carefully. Recently, intravenous anesthesia with propofol has been established as a standard method of anesthesia. Mask anesthesia, when performed by experienced anesthesiologists, is often safer than local anesthesia, during which respiratory and circulatory management is often difficult.

ii) Maintenance of Body Temperature During Surgery
Hypothermia during surgery is an obvious risk factor for perioperative cardiac events in patients at risk for heart disease. Active warming to maintain body temperature is recommended.$^{23}$

iii) Perioperative Pain Control
Most cardiac events in patients undergoing noncardiac surgery occur during postoperative period. In facilitating early ambulation, normalizing blood coagulation, and preventing postoperative pulmonary embolism, adequate postoperative pain control is quite important. Patient-controlled analgesia (PCA) is a method with high patient satisfaction, and pain scores achieved with PCA are lower than with other analgesic methods. For example, epidural or spinal anesthesia with narcotics is beneficial in many respects, and physicians should consider use of this method when it is possible.

iv) Perioperative Nitroglycerin
Perioperative nitroglycerin therapy may be beneficial in high-risk patients with signs of myocardial ischemia without hypotension who have received nitroglycerin, but is contraindicated for patients with hypovolemia or signs of hypotension.

(3) Prevention of Cardiac Complications During Emergency Surgery
Patients who require emergency surgery often have conditions that may affect the heart such as anemia and hypovolemia. Physicians must often start emergency surgery without appropriate evaluation of the risk of surgery and obtaining information on previous treatment of heart disease. In this situation, patients are likely to develop complications including
cardiac complications. Physicians must pay special attention to possible ischemic heart disease, since emergency surgery is often initiated without performing coronary angiography, namely, the only method for its definitive evaluation.

i) Preoperative Management
Especially in patients with trauma, it is often difficult to obtain sufficient information before emergency surgery. It is preferable that physicians be aware of the possibility of heart disease. Physicians should assess the presence/absence of known risk factors for heart disease whenever possible. When arteriosclerotic lesions or other findings known to be associated with heart disease are present, physicians should assume that the patient has heart disease and manage them as such. A history of “asthma” is a word of caution, and may in fact represent heart failure.

Physicians should carefully examine the ECG for findings suggestive of myocardial ischemia, and consider coronary artery disease a possible cause of ventricular extrasystole, bradycardia, and/or blocks. When left ventricular hypertrophy is present, the presence of aortic stenosis or cardiomyopathy should be suspected.

Chest X-ray should be carefully evaluated for cardiomegaly, pulmonary congestion, and aortic calcification.

It is quite important to improve general condition before surgery. Anemia, hypovolemia, poor oxygenation, and peripheral hypoperfusion must be treated to the extent possible.

ii) Intraoperative Management
The ECG is often the only continuous monitor available during surgery. Since bleeding and evaporation may exacerbate hypovolemia and anemia, patients should be carefully monitored for myocardial ischemia. When ST change, hypotension, or frequent arrhythmia occurs, hemodynamics and cardiac function should be evaluated using the ECG and transesophageal echocardiography, and appropriate treatment should be given. When heart failure or arrhythmia occurs, it is essential to control water balance, electrolyte balance, and anemia, if present. Since the incidence of ventricular fibrillation increases when the body temperature is 34°C or lower, hypothermia should be prevented. Patients are especially prone to develop hypothermia during surgery with large-volume transfusion and/or rapid fluid administration and extensive surgery. It should be noted that rapid transfusion may cause hypocalcemia.

iii) Postoperative Management
Appropriate postoperative management including adjustment of fluid volume is important to prevent cardiac overload, especially in critically ill patients. Postoperative hypoglycemia may cause osmotic diuresis and consequent dehydration. Following emergency surgery, water and electrolyte balance are prone to be out of order. If hypokalemia is present, patients are more prone to develop atrial fibrillation and ventricular extrasystole.

Prolonged bed rest after emergency surgery may induce venous thrombosis and pulmonary embolism. If a venous line was placed in femoral vein or leg vein before surgery, it should be changed to a new position in the upper extremities after the patient’s condition has stabilized.

iv) Injuries to the Heart or Thoracic Great Vessels Associated With Multiple Trauma
Thoracic aorta injury account for many death after blunt trauma, although their frequency among total cases is not high. Thoracic aorta injury often occur in the ascending aorta and the proximal descending aorta. Since patients with ascending aorta injury often fall into catastrophic condition rapidly, physicians treat patients mainly with injuries of the proximal descending aorta. When chest X-ray reveals a widened mediastinum and a large volume of pleural effusion or when echocardiography reveals pericardial effusion, CT and transesophageal echocardiography should be performed to exclude aortic injury prior to noncardiac surgery.

Priority of treatment in patients with multiple trauma depends on individual cases. When the aorta is repaired first, blood loss during extracorporeal circulation will be a concern, while if noncardiac surgery is performed first, perioperative aortic rupture may develop. When aortic injury is managed conservatively, the patient should be carefully evaluated to find out conditions requiring aggressive surgical treatment. CT is the most useful method for objective evaluation in such circumstances.

3. Pregnancy/Delivery and Heart Disease

(1) Pregnancy and Delivery in Patients With Congenital Heart Disease
Pregnancy and delivery pose no serious threats in women who had undergone corrective surgery for simple heart malformation or tetralogy of Fallot and have New York Heart Association (NYHA) Class II or better cardiac function. However, women should be carefully evaluated for remaining defects, since heart failure and/or arrhythmia may develop and cyanosis may be exacerbated during pregnancy and delivery. Table 7 outlines the safety of pregnancy and delivery for women with uncorrected congenital heart disease.

Although cases of pregnancy and delivery in women with cyanotic complex cardiac anomalies such as complete transposition of the great arteries, tricuspid atresia, and univentricular heart who have or have not undergone corrective surgeries have been reported, the risk of death and complications including fetus associated with pregnancy is quite high in this population. Live birth is rare among women with an arterial oxygen saturation ≤85%. Among women with

| Table 7. Pregnancy and Delivery in Patients With Uncorrected Congenital Heart Disease |
|---------------------------------|---------------------------------|
| Atrial septal defect            | No problem in most cases       |
| Ventricular septal defect       | No problem in most cases       |
| Patent ductus arteriosus        | No problem in most cases       |
| Congenital aortic stenosis      | Pressure gradient of ≤50mmHg   |
|                                 | (No problem if ≤50mmHg)        |
| Coarctation of the aorta        | Pressure gradient of ≤20 to    |
|                                 | 30mmHg, asymptomatic           |
| Pulmonary artery stenosis       | Pressure gradient of ≤80mmHg   |
| Tetralogy of Fallot             | Pregnancy and delivery are    |
|                                 | dangerous if hematocrit is ≥60%|
|                                 | arterial oxygen saturation is  |
|                                 | ≤80%; or increased right      |
|                                 | ventricular pressure had      |
|                                 | developed or syncope has       |
| Cyanotic complex cardiac        | No consensus                   |
| anomalies                       |                                 |
| Eisenmenger syndrome            | Contraindicated                |
| Marfan syndrome                 | No expansion of the ascending  |
|                                 | aorta                         |

JCS Joint Working Group
Allergic to ampicillin, amoxicillin, or penicillin.

Low-risk patients (Amoxicillin)

Table 8. Recommendations for Anticoagulation Therapy During Pregnancy in Patients With Mechanical Prosthetic Valves

a) Weeks 1 through 35
Class I

1. The decision whether to use heparin during the first trimester or to continue oral anticoagulation throughout pregnancy should be made after full discussion with the patient and her partner; if she chooses to change to heparin for the first trimester, she should be made aware that heparin is less safe for her, with a higher risk of both thrombosis and bleeding, and that any risk to the mother also jeopardizes the baby.

2. High-risk women (a history of thromboembolism or an older-generation mechanical prosthesis in the mitral position) who choose not to take warfarin during the first trimester should receive continuous unfractionated heparin intravenously in a dose to prolong the mid-interval (6 hours after dosing) aPTT to 2 to 3 times control. Transition to warfarin can occur thereafter.

Class IIa

In patients receiving warfarin, INR should be maintained between 2.0 and 3.0 with the lowest possible dose of warfarin, and low-dose aspirin should be added.

Class IIb

Women at low risk (no history of thromboembolism, newer low-profile prosthesis) may be managed with adjusted-dose subcutaneous heparin (17,500 to 20,000 U BID) to prolong the mid-interval (6 hours after dosing) aPTT to 2 to 3 times control.

b) After the 36th week
Class IIa

1. Warfarin should be stopped no later than week 36 and heparin substituted in anticipation of labor.

2. If labor begins during treatment with warfarin, a Caesarian section should be performed.

3. In the absence of significant bleeding, heparin can be resumed 4 to 6 hours after delivery and warfarin begun orally.

Table 9. Antibiotic Prophylaxis During Labor and Delivery

1. Standard regimen (Ampicillin, gentamicin, and amoxicillin)
   - Initial dose
     - 30 minutes before procedure: Ampicillin 2 g plus gentamicin 1.5 mg/kg (maximal dose 80 mg) IV or IM
     - Next dose
     - 6 hours after initial dose: Amoxicillin 1.5 g PO (if this is not possible, repeat the initial-dose regimen 8 hours after initial dose)

2. Allergic to ampicillin, amoxicillin, or penicillin (Vancomycin and gentamicin)
   - Initial dose
     - 1 hour before procedure: Vancomycin 1 g IV (over ≥1 hour) plus gentamicin 1.5 mg/kg (maximal dose 80 mg) IV or IM
     - Next dose (if necessary)
     - 8 hours after initial dose: Repeat the initial-dose regimen

3. Low-risk patients (Amoxicillin)
   - Initial dose
     - 1 hour before procedure: Amoxicillin 3 g PO
     - Next dose
     - 6 hours after initial dose: Amoxicillin 1.5 g PO

IV, intravenous injection; IM, intramuscular injection; PO, oral administration.


cause hypovolemia and result in suboptimal uteroplacental circulation.30,38 Percutaneous mitral valvuloplasty may be indicated for severe mitral stenosis before pregnancy. When heart failure not responding to medical therapy develops during pregnancy, physicians should consider percutaneous mitral valvuloplasty.30 Pregnancy and delivery in women with acquired aortic stenosis should be treated similarly to that in those with congenital aortic stenosis. Mitral insufficiency and aortic insufficiency may often be treated with medical therapy when patient’s condition is not severe. Angiotensin converting enzyme (ACE) inhibitors must be avoided during pregnancy, since these drugs will affect the development of the fetus. Surgery before pregnancy should be considered when women with severe valvular disease wish to become pregnant.

(3) Pregnancy and Delivery in Patients With Mechanical Prosthetic Valves

Table 8 shows the recommendations for anticoagulation therapy in pregnant women with mechanical prosthetic valves.39 Both warfarin and heparin may pose the risk of bleeding and thrombosis in the mother and the fetus. Warfarin, which passes through the placenta, increases the incidences of spontaneous abortion, premature birth, and stillbirth, and causes fetal malformation in 0 to 20% of mothers receiving warfarin (the average incidence in the four most recent reports is 1.6%). The risk of fetal malformation is especially high when warfarin is administered during weeks 6 to 12 of gestation.38 Although heparin therapy is considered safe, since it does not pass through the placenta, long-term heparin therapy may cause such as noninfective abscess, osteoporosis, thrombocytopenia, and bleeding.39 It has been reported that thromboembolism occurs in 4 to 14% of patients receiving adequate anticoagulation therapy with heparin.40-42

Bioprosthetic valves are believed to be a good option for women who wish to become pregnant, since anticoagulation

Table 8

<table>
<thead>
<tr>
<th>aPTT, activated partial thromboplastin time; INR, international normalized ratio; U, unit; BID, twice a day. Adapted from J Am Coll Cardiol 1998; 32: 1486–1588, with permission from Elsevier Inc.</th>
</tr>
</thead>
<tbody>
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<td>a) Weeks 1 through 35</td>
</tr>
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</tr>
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</tr>
<tr>
<td>2. High-risk women (a history of thromboembolism or an older-generation mechanical prosthesis in the mitral position) who choose not to take warfarin during the first trimester should receive continuous unfractionated heparin intravenously in a dose to prolong the mid-interval (6 hours after dosing) aPTT to 2 to 3 times control. Transition to warfarin can occur thereafter.</td>
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<tr>
<td><strong>Class IIa</strong></td>
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<tr>
<td>In patients receiving warfarin, INR should be maintained between 2.0 and 3.0 with the lowest possible dose of warfarin, and low-dose aspirin should be added.</td>
</tr>
<tr>
<td><strong>Class IIb</strong></td>
</tr>
<tr>
<td>Women at low risk (no history of thromboembolism, newer low-profile prosthesis) may be managed with adjusted-dose subcutaneous heparin (17,500 to 20,000 U BID) to prolong the mid-interval (6 hours after dosing) aPTT to 2 to 3 times control.</td>
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</tr>
</tbody>
</table>

(2) Pregnancy and Delivery in Women With Valvular Disease

Pregnant women with mild or moderate mitral stenosis may receive diuretics and β blockers to prevent and treat congestive heart failure and tachycardia, respectively. Diuretics should be used carefully, since excessive use of them may
therapy is not necessary in patients with such valves unless they have a history of atrial fibrillation or thromboembolism. However, it is known that bioprothetic valves deteriorate more rapidly in young patients, and reports have noted that deterioration of bioprothetic valves is further promoted during pregnancy.38,42,43 Physicians should adequately explain to patients the fact that they may have to undergo reoperation earlier as a result of pregnancy.

(4) Prevention of Infection During Pregnancy and Delivery in Patients With Heart Disease
The incidence of infective endocarditis after uncomplicated vaginal delivery in women with heart disease is believed to be low, and it is not generally recommended that patients in this population receive antibiotic prophylaxis. However, antibiotic prophylaxis during delivery is performed in patients with prosthetic valves, those with a history of endocarditis, those following corrective surgery of congenital heart malformation (depending on condition), those following shunt surgery, and those with mitral prolapse or insufficiency.30 Table 10 presents the current findings on cardiovascular drugs commonly used during pregnancy.30,39,44

(5) Effects of Cardiovascular Drugs During Pregnancy
Table 10 presents the current findings on cardiovascular drugs commonly used during pregnancy.30,39,44

**Table 10. Effects of Cardiovascular Drugs During Pregnancy**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Potential fetal adverse effects</th>
<th>Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warfarin</td>
<td>Fetal bleeding in utero, embryopathy, CNS abnormalities</td>
<td>Unsafe</td>
</tr>
<tr>
<td>Heparin</td>
<td>None reported</td>
<td>Probably safe</td>
</tr>
<tr>
<td>Digoxin</td>
<td>Low birth weight</td>
<td>Safe</td>
</tr>
<tr>
<td>Quinidine</td>
<td>Toxic dose may induce premature labor and cause damage to fetal eighth cranial nerve</td>
<td>Safe</td>
</tr>
<tr>
<td>Procaainamide</td>
<td>None reported</td>
<td>Not established</td>
</tr>
<tr>
<td>Disopyramide</td>
<td>May initiate uterine contractions</td>
<td>Not established</td>
</tr>
<tr>
<td>Lidocaine</td>
<td>In high blood levels and fetal acidosis may cause CNS depression</td>
<td>Safe</td>
</tr>
<tr>
<td>Mexiletine</td>
<td>Fetal bradycardia, intraurine growth retardation, low Apgar score, neonatal hypoglycemia, neonatal bradycardia, neonatal hypothyroidism</td>
<td>Not established</td>
</tr>
<tr>
<td>Flecainide</td>
<td>One reported fetal death</td>
<td>Not established</td>
</tr>
<tr>
<td>Amiodarone</td>
<td>Intraurine growth retardation, prematurity, hypothyroidism</td>
<td>Unsafe</td>
</tr>
<tr>
<td>Calcium blockers</td>
<td>Fetal distress due to maternal hypotension</td>
<td>Not established</td>
</tr>
<tr>
<td>β blockers</td>
<td>Intraurine growth retardation, apnea at birth, bradycardia, hypoglycemia, hyperbilirubinemia</td>
<td>Safe</td>
</tr>
<tr>
<td>β2 blockers</td>
<td>β2 blockers may initiate uterine contractions</td>
<td>Not established</td>
</tr>
<tr>
<td>Hydralazine</td>
<td>None reported</td>
<td>Safe</td>
</tr>
<tr>
<td>Sodium nitroprusside</td>
<td>Potential thiocyanate toxicity with high dose, fetal mortality with nitroprusside in animal studies</td>
<td>Potentially unsafe</td>
</tr>
<tr>
<td>Organic nitrates</td>
<td>Fetal bradycardia</td>
<td>Not established</td>
</tr>
<tr>
<td>ACE inhibitors</td>
<td>Skull ossification defect, intraurine growth retardation, premature deliveries, low birth weight, oligohydramnios, neonatal renal failure, anemia and death, limb contractures, patent ductus arteriosus</td>
<td>Unsafe</td>
</tr>
<tr>
<td>Diuretics</td>
<td>Impairment of uterine blood flow, thrombocytopenia, jaundice, hyponatremia, bradycardia</td>
<td>Potentially unsafe</td>
</tr>
</tbody>
</table>

CNS, central nervous system; ACE, angiotensin converting enzyme. Adapted from J Am Coll Cardiol 1998; 32: 1486–158839, with permission from Elsevier Inc.

**Il Descriptions**

1. **Ischemic Heart Disease**

(1) Diagnosis
Physicians should interview patients for subjective symptoms, personal and family history of ischemic heart disease, and the presence/absence of coronary risk factors and conditions frequently associated with ischemic heart disease. It should be noted that patients with diabetes and elderly patients often do not complain of significant symptoms of angina. It is important to check for exertional angina as well as atypical angina due to coronary spasm. It is common for the chest X-ray to reveal few findings typical of ischemic heart disease, and ECG at rest in the absence of anginal attacks is normal. Definitive diagnosis of ischemic heart disease can be made with coronary angiography. Figure 1 shows a flow chart for considering indications for coronary angiography according to risk of noncardiac surgery.21

(2) Severity Evaluation and Risk
The severity of myocardial ischemia is correlated with angiographic findings such as the number of affected vessels, level of stenosis, and presence/absence of stenosis in the left main trunk, as well as the severity of angina. Evaluation of cardiac function and degree of mitral regurgitation is quite important for appropriate perioperative management of patients undergoing noncardiac surgery.

(3) Special Management
The indications for coronary revascularization as a part of management of patients undergoing noncardiac surgery are basically identical to those in patients in general. However, transcatheter intervention on PCI is especially preferred to bypass surgery in patients whose noncardiac disease has a poor prognosis and those in poor general condition including bleeding tendency.

There are several issues for patients whom CABG is indicated. Off-pump CABG and minimally invasive direct coro-
In patients undergoing PCI prior to noncardiac surgery, it has been recommended that conventional PCI without stenting be performed about 1 to 2 weeks prior to noncardiac surgery. However, PCI using stents, especially DES, requires potent anticoagulation therapy for a longer period of time, which may pose risks during noncardiac surgery and significantly affect the timing of noncardiac surgery. The use of DES should be considered only in selected cases (Table 4).

(4) Intraaortic Balloon Pumping

Although intraaortic balloon pumping (IABP) may increase coronary blood flow, support cardiac function, and decrease afterload, the efficacy of perioperative IABP use in patients...
undergoing noncardiac surgery has not been established. IABP support may be continued before and throughout surgery. A trocar may be placed in the femoral artery before surgery to ensure prompt insertion of IABP, or emergency IABP may be initiated during or after surgery. It should be noted that certain body positions hinder the use of IABP.

(5) Precautions Regarding Anesthesia and Perioperative Management in Patients Undergoing Noncardiac Surgery
Anesthesia should be induced with fentanyl, which causes fewer hypotension, and benzodiazepines such as midazolam and diazepam, and should be maintained with neuroleptanalgesia (NLA). Combined use with epidural anesthesia has been reported to be useful. When coronary vasodilators are used, physicians should be aware of the characteristics of drugs, i.e. low incidence of hypotension (Nitrol and nicorandil), short duration of action after withdrawal (nitroglycerin), and inhibition of spasm and slowing of heart rate (diltiazem), and should select appropriate drugs according to patient’s condition. Small doses of dopamine may be useful to treat hypotension during surgery. Patients with severe coronary spasm should be treated with adequate doses of calcium blockers, undergo measures to prevent hypothermia and respiratory alkalosis, and have their blood pressure adequately controlled. During noncardiac surgery in patients with frequent ventricular extrasystoles, physicians should infuse lidocaine continuously, monitor and maintain serum potassium level, and keep an external defibrillator ready for use. “Precautions for anesthesia in cardiac surgery” should be followed.

2. Valvular Heart Disease
When cardiac murmur is heard prior to noncardiac surgery, physicians must identify the cause of the murmur, consider whether the murmur reflects a serious condition or not, whether further assessment is needed to investigate its severity, and whether prevention of infectious endocarditis is required. Diastolic murmurs are almost always pathologically significant, and diagnosis and investigation of them are required. It is quite rare for functional murmurs with a grade ≥III to IV on the Levine scale to be heard, but the loudness of murmurs depends on body size and does not accurately reflect the severity of valvular disease.

(1) Valvular Diseases and Noncardiac Surgery
i) Aortic Stenosis
Severe aortic stenosis is one of the most important risk factors for cardiac complications during noncardiac surgery. It is preferable that noncardiac surgery be avoided or aortic valve replacement be performed prior to noncardiac surgery in patients with symptomatic aortic stenosis with a left ventricular-aortic pressure gradient of ≥50mmHg, syncope, anginal pain, and/or left heart failure (Figure 2).

ii) Mitral Insufficiency
No specific measures are required during noncardiac surgery in patients with mild or moderate mitral regurgitation and without signs/symptoms of heart failure. However, antibiotic prophylaxis is needed to prevent infectious endocarditis. Mitral valve surgery such as valvuloplasty and prosthetic valve replacement should be performed first in patients with grade ≥III mitral regurgitation and signs/symptoms of heart failure. It should be noted that mitral insufficiency often cause a seemingly favorable left ventricular ejection fraction. Perioperative antibiotic therapy is required to prevent infections not only in patients with clinically significant mitral valve prolapse but also in asymptomatic patients in whom echocardiography reveals findings of mitral regurgitation or thickened valve leaflets.

iii) Tricuspid Insufficiency
Since patients with severe tricuspid insufficiency may exhibit significant hepatic congestion possibly resulting in hepatic disorders such as hepatic cirrhosis, modification of treatment strategies is often required if high-risk noncardiac surgery is to be performed.

iv) Aortic Insufficiency
In patients with aortic regurgitation of grade II or less, noncar-
Cardiac surgery may be performed before cardiac surgery when appropriate measures including the prevention of infectious endocarditis are taken. In patients with aortic regurgitation of grade III or higher and those with clinical symptoms, physicians should be aware that the risk of noncardiac surgery is, depending on the type of surgery performed, often significantly high when performed prior to surgical treatment of aortic regurgitation. Fatal arrhythmia may occur in this patient population, and perioperative management is difficult. Although the risk of noncardiac surgery varies according to the type of procedure, it is preferable that surgical treatment of aortic valves be performed first before left heart function has significantly exacerbated.

(2) Treatment of Valvular Disease Before Noncardiac Surgery

Cardiac surgery is the only option available for patients with severe valve insufficiency. When patients with severe mitral stenosis need emergency noncardiac surgery such as repair for serious gastrointestinal bleeding, catheter balloon valvuloplasty is believed to reduce the risks of such surgery, and therefore to be beneficial. However, mitral valve replacement is required in patients with atrial fibrillation, those with left atrial thrombus, and patients with very severe valve lesions. Balloon valvuloplasty for aortic stenosis is not recommended. Since only limited data are available to this procedure, and the risk in elderly patients is quite high.

(3) Management of Patients With Valvular Disease During Noncardiac Surgery

In patients with valve regurgitation, low peripheral vascular resistance is important. Hypertension is harmful, vasodilators should be used if necessary. On the other hand, patients with severe valve stenosis are often unable to accommodate hemodynamic changes due to fluid overload. Volume overload induces congestive heart failure, while excessive dehydration may cause circulatory collapse. Water balance should be managed strictly, especially in patients with aortic and mitral stenoses regardless of the severity of valve lesions. Since arrhythmia often occurs in patients with valvular diseases, appropriate antiarrhythmic therapy and heart rate control play key roles during the perioperative period.

3. Treatment of Congenital Heart Disease Before Corrective Surgery

The mortality after noncardiac surgery in neonates and infants with congenital heart disease is about twice that in those without it, and it has been reported that the presence of congenital heart disease significantly increases the risk of mortality even after minor noncardiac surgery.

(1) Neonates and Infants

The prevalence of heart disease in neonates is 13.2 to 43% among those with esophageal atresia, 9 to 12.1% among those with anal atresia, 13.9 to 45.5% in those with exomphalos, 17.9 to 33% in those with duodenal atresia, and 10.5 to 12.5% in those with diaphragmatic hernia. Children born with conditions requiring surgical treatment immediately after birth should be evaluated with echocardiography.

Although the methods of surgical correction of anal atresia and intestinal atresia/stenosis are well established, the mortality rates of neonates and infants with large exomphalos and diaphragmatic hernia are still high. In such infants, it is quite difficult to perform surgical correction of heart disease during early infancy. In children with esophageal atresia and heart disease, correction of esophageal atresia is often performed first. However, no consensus has been reached regarding the timing of heart surgery (before or after correction of esophageal atresia) or the strategy of treatment for esophageal atresia (one- or two-stage corrective surgery).

In neonates with congenital heart diseases that increase pulmonary blood flow, surgical correction of noncardiac disease may be performed during the first several days of life, during the period when pulmonary vascular resistance remains high, while in neonates with congenital heart diseases that decrease pulmonary blood flow, noncardiac surgery may be performed when cyanosis has improved by treatment with prostaglandin (PG) E1 (0.05 to 0.1 μg/kg/min) to a stable hemodynamic condition. No consensus exists regarding treatment strategy or the order of cardiac and noncardiac surgeries in patients with complex heart disease who exhibit cyanosis and increased pulmonary blood flow.

Many types of congenital heart diseases can be diagnosed...
Major risk factors: Fatal cardiac complications may occur. Cardiac repair may be indicated first in some conditions.

- Eisenmenger syndrome
- Significant persistent lesions/complications following reparative surgery
- Decompensated heart failure
- Severe hypoxemia (untreated cyanotic heart disease, following palliative surgery)
- Severe arrhythmia

Intermediate risk factors: Factors that increase the risk of perioperative cardiac complications. Patient’s condition should be carefully evaluated.

- Moderate persistent lesions/complications following reparative surgery
- Compensated heart failure
- Following palliative surgery (hypoxemia is present)

Recommended management: Patients should be admitted to the intensive care unit (ICU) for perioperative management by specialists. Discontinuation or postponement of non-urgent noncardiac surgery is preferable. If corrective treatment (including catheter techniques, and/or pacemaker placement) is indicated for heart disease, it should be treated first.

Mild risk factors: Cardiovascular abnormalities that have not themselves been demonstrated to increase the risk of perioperative cardiac complications.

- Congenital heart disease not requiring repair
- Patients after cardiac repair in whom continued treatment is not required

Recommended for heart disease, it should be treated first.

Table 11. Cardiac Risk Factors in Adult Patients With Congenital Heart Disease

<table>
<thead>
<tr>
<th>Risk Factor</th>
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<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>* Severe arrhythmia</td>
</tr>
<tr>
<td>2) Intermediate risk factors: Factors that increase the risk of perioperative cardiac complications. Patient’s condition should be carefully evaluated.</td>
<td></td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>* Compensated heart failure</td>
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<tr>
<td></td>
<td>* Following palliative surgery (hypoxemia is present)</td>
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</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Noncardiac surgery is planned, patients should be evaluated for cardiovascular abnormality in detail. If the results are poor, cardiac surgery or catheter intervention prior to noncardiac surgery may be considered.

(2) Cardiac Risk Factors During the Perioperative Period

Table 11 lists common risk factors in adult patients with congenital heart disease.21

(3) Examinations Used in Preoperative Evaluation of Risk Factors

All patients with congenital heart disease require preoperative evaluation with 12-lead ECG, chest X-ray, and echocardiography. While arterial blood gas analysis, pulmonary ventilation/perfusion scintigraphy, and Holter ECG may be necessary in some cases, exercise stress testing and cardiac catheterization are indicated for only a small number of patients.

(4) Criteria for Severity of Persistent Heart Lesions

Table 12 presents the criteria for severity of heart lesions remaining after corrective surgery for congenital heart disease.64

(5) Problems Following Corrective Surgery

Following corrective surgery for acyanotic congenital heart disease, patients may experience embolism secondary to atrial arrhythmia/fibrillation; congestive heart failure due to a residual shunt; severe PH; mitral insufficiency/stenosis or left ventricular outflow obstruction following correction of atrioventricular septal defect; and restenosis of repaired aortic coarctation, among other conditions.

Patients born with cyanotic complex cardiac anomaly may often require reoperation at a later age even if they are treated with corrective surgery. Depending on the procedure of the corrective surgery, patients may exhibit characteristic hemodynamic changes for which special management may be needed during noncardiac surgery. Patients with the conditions listed in Table 12,64 valvular regurgitation, or serious arrhythmia must be treated especially carefully. Patients with following conditions need special care: for patients after atrial switch operation, vena cava obstruction, pulmonary venous stenosis, right ventricular dysfunction which acts as systemic ventricle. For patients after atrial switch operation, pulmonary...
Table 13. AHA Recommendations on Prophylactic Regimens for the Prevention of Infectious Endocarditis

1. Dental/upper respiratory tract procedures

(1) Standard
- Amoxicillin 3g PO (1 hour before procedure) + amoxicillin 1.5g PO (6 hours after)

(2) High-risk patients
- Ampicillin 2g + gentamicin 1.5mg/kg IV or IM (30 minutes before procedure) + amoxicillin 1.5g PO (6 hours after)

(3) Allergic to amoxicillin/penicillin
- Erythromycin 1g PO (2 hours before procedure) + erythromycin 0.5g PO (6 hours after)
- Clindamycin 300mg PO (1 hour before procedure) + clindamycin 150mg PO (6 hours after)

2. Gastrointestinal/genitourinary procedures

(1) Standard
- Ampicillin 2g + gentamicin 1.5mg/kg IV or IM (30 minutes before procedure), amoxicillin 1.5g PO (6 hours after)

(2) Allergic to amoxicillin/penicillin
- Vancomycin 1g IV + gentamicin 1.5mg/kg IV or IM (1 hour before procedure); may be repeated 8 hours after.

(3) Low-risk patients
- Amoxicillin 3g PO (1 hour before procedure) + amoxicillin 1.5g PO (6 hours after)

Table 14. Indications for Surgical Treatment (Including Interventions) of Aortic Aneurysms

Indications for surgical treatment of true aortic aneurysm

Class I:
- Ruptured aortic aneurysm
- Ascending aortic aneurysm associated with severe complications (aortic insufficiency associated with heart failure, or cardiac tamponade)
- Sinus of Valsalva aneurysm associated with intracardiac shunt (ruptured sinus of Valsalva aneurysm)
- True TAA ≥6cm of maximal diameter

Class IIa:
- True TAA ≥5cm in diameter in patients with Marfan syndrome
- True TAA 5 to 6cm in diameter
- Saccular aortic aneurysm
- True TAA associated with rapid expansion in diameter (>5mm/6 months)

Class IIb:
- True TAA 4 to 5cm in diameter

Indications for surgical treatment of false aortic aneurysm

Class I: All diagnosed false aortic aneurysms not associated with other organ injuries

Class IIb: False aortic aneurysm associated with other organ injuries

Indications for surgical treatment of dissecting aortic aneurysm

Class I:
- Type A acute dissection with patent false lumen (type I, II dissecting, type III retrograde)
- Aortic dissection with severe complications which surgery may improve or prevent progression of ruptured false lumen, rediscission, cardiac tamponade, circulatory disorder associated with loss of consciousness and paralysis, aortic insufficiency associated with heart failure, myocardial infarction, blood flow disturbance in the visceral organs or the extremities
- Aortic dissection associated with aortic expansion (>6cm of maximal diameter)
- Chronic dissection associated with rapid aortic expansion in diameter (>5mm/6 months)

Class IIa:
- Aortic dissection not responding to blood pressure control and pain drug control
- Aortic dissection associated with Marfan syndrome

Class IIb:
- Type A acute dissection with occluded false lumen
- Aortic dissection 5 to 6cm of maximal diameter

TAA, thoracic aortic aneurysm.

5. Aortic Diseases

(1) Diagnosis and Evaluation of Thoracic Aortic Aneurysm During Noncardiac Surgery

Table 14 lists the indications for surgical treatment of thoracic aortic aneurysm (TAA).

Most patients with true aortic aneurysm, other than those with ruptured aortic aneurysm or impending aneurysm rupture, are asymptomatic. When aortic aneurysm is suspected on chest X-ray or other examinations, contrast CT or magnetic resonance imaging (MRI) should be performed to confirm the diagnosis. Avoidance of angiography is increasingly common now.

False aortic aneurysm develops mainly after injury, but is often overlooked during the period immediately after its development. Since the risk of rupture is high, patients diagnosed with false aortic aneurysm should be transferred as soon as possible to institutions where appropriate treatment is available.

artery stenosis. Patients who had undergone Fontan operation are prone to heart failure. About 10 years after the Fontan operation, patients are prone to develop supraventricular arrhythmias, thromboembolism, protein-losing gastroenteropathy, hepatic congestion, hepatic dysfunction, decrease in cardiac function, or other abnormal conditions, and thus require careful management.

(6) Problems With Uncorrected Congenital Heart Disease

No special perioperative management is required for noncardiac surgery in patients with congenital heart disease not indicated for surgery such as small atrial or ventricular septal defect and acyanotic tetralogy of Fallot. Many patients with large uncorrected left-to-right shunt exhibit Eisenmenger syndrome, and the risk of noncardiac surgery is quite high in these patients. Patients with cyanosis must be carefully managed for hypoxemia, polycythemia, prevention of visceral disorder, brain abscess, and infectious endocarditis.

(7) Important Aspects of Perioperative Management

Perioperative management of patients with a history of congenital heart disease who are undergoing noncardiac surgery is performed mainly to prevent heart failure, hypoxemia, and arrhythmias. Selective pulmonary vasorelaxants are effective in patients with right ventricular failure. It is important to prevent infectious endocarditis, air embolism, and brain abscess in patients with cyanotic heart disease. Table 13 lists the AHA’s recommendations on antibiotic treatment for the prevention of infectious endocarditis.48
Patients suspected to have acute aortic dissection should undergo contrast CT to confirm the diagnosis under strict blood pressure control. Treatment of type A acute aortic dissection should be prioritized even when noncardiac surgery is planned. Antihypertensive therapy is the treatment of first choice for patients with type B acute aortic dissection.

(2) Management of Aortic Aneurysm During Noncardiac Surgery

During noncardiac surgery, patients with aortic aneurysms should be carefully observed for ischemic heart disease and severe hypertension, that frequently co-exist. Although there have been few reports about aortic aneurysm rupture during the perioperative period of noncardiac surgery, perioperative blood pressure control has been reported to be effective in preventing rupture of aortic aneurysms. 69–71 When hyper-
tension is mild or moderate and no abnormal findings related to hypertension are observed, noncardiac surgery may not be postponed. However, patients with severe hypertension require careful blood pressure control throughout the perioperative period. In patients who cannot take drugs orally and who are going to undergo emergency surgery, intravenous infusion of antihypertensives is recommended.\textsuperscript{72}

(3) Priority of Surgeries and Simultaneous Surgery
Abdominal aortic aneurysms (AAA) ≥6 cm in diameter should be treated surgically before noncardiac surgery even when the latter involves surgery of malignant disease, or should be treated concomitantly during noncardiac surgery in the case of abdominal surgery.\textsuperscript{71,74}

Figure 3 shows the guidelines for priority of noncardiac surgery and TAA surgery. Priority depends on the pathological conditions of aortic aneurysms and noncardiac diseases. Further investigation of optimal management of aortic aneurysms in patients receiving noncardiac surgery is needed.

(4) Stent Grafting
Although stent grafting for aortic aneurysm is not a standard treatment procedure in Japan, and is only available in limited institutions, it may be used for the treatment of aortic aneurysms depending on the anatomical and structural characteristics of lesions. It has been found that stent grafting improves the short- and long-term prognosis of patients with relatively low risk of surgical complications who are likely to tolerate conventional artificial vascular graft implantation with thoracotomy or laparotomy, while it does not substantially improve the prognosis of high-risk patients.\textsuperscript{75} Further clinical data and analyses are needed to determine the efficacy and safety of this technique. However, if outcome does not differ between endovascular stent grafting and surgical grafting, stent grafting is worth considering because it is useful, less invasive option to treat aortic aneurysms in patients undergoing elective noncardiac surgery to ensure a favorable clinical course during the perioperative period of noncardiac surgery.

(5) Rare Heart Diseases
i) Aortitis Syndrome (Takayasu Disease)
Surgical treatment is required in 13\% of patients with aortitis syndrome. To ensure the safety of noncardiac surgery, patients should be carefully observed for hypertension due to renal artery stenosis and heart failure associated with aortic regurgitation. Patients with active inflammation as suggested by a high CRP level should be treated with corticosteroids to control inflammation and corticosteroid therapy should be reduced before noncardiac surgery when it is not urgently required.

ii) Marfan Syndrome
The outcome of cardiovascular surgery in patients with Marfan syndrome is excellent.\textsuperscript{76,77} When appropriate cardiovascular evaluation does not reveal abnormal findings, patients with Marfan syndrome may usually undergo conventional noncardiac surgery.

(6) Management of Aortic Aneurysms in Patients With Other Heart Diseases
i) Ischemic Heart Disease
It has been reported that coronary lesions are observed in one-eights of patients with aortic dissection and one-thirds of patients with true aortic aneurysm. Ischemic heart disease is more common among patients with AAA.\textsuperscript{72} Ischemic heart disease should be carefully managed during the perioperative period of patients undergoing aortic aneurysm surgery. IABP support is often not feasible in this patient population. Since hemodynamics during the perioperative period are often unstable due to hypertension and systemic arteriosclerosis, management of ischemic heart disease is more important during aortic surgery than other types of surgery.

Patients with aortic disease requiring elective, nonurgent surgery and symptomatic or severe coronary artery disease should undergo coronary surgery first, coronary surgery and aortic aneurysm surgery simultaneously, or coronary intervention first. DES, which require long-term treatment with potent antiplatelet drugs, are not feasible in patients planned to undergo aortic aneurysm surgery after coronary stenting. When simultaneous surgery is selected, hybrid treatment, namely, off-pump coronary bypass surgery and transcatheter coronary intervention should be considered. Patients with aneurysms in the descending aorta or thoracoabdominal aorta may simultaneously undergo aortic surgery and bypass surgery to the left anterior descending artery and/or the circumflex coronary artery.

ii) Valvular Heart Disease
When aortic surgery and valve surgery can be performed through the same incision, simultaneous surgery is feasible provided that cardiac function is normal. Although no consensus has been reached regarding the optimal surgical treatment of aortic lesions and valvular lesions which cannot be treated through the same incision, it is important to consider stent grafting as an option.

6. Peripheral Arterial Disease (Abdomen, Neck, and Lower Extremities)

Table 15 shows guidelines for evaluation and management of patients who have AAA, carotid artery stenosis, or arteriosclerosis obliterans (ASO) of the lower extremities and are to undergo noncardiac surgery under general anesthesia (cases of emergency surgery for noncardiac diseases are excluded). Since peripheral arterial disease may develop as a result of arteriosclerosis, patients diagnosed with a vascular lesion must be examined for other vascular lesions.

(1) Abdominal Aortic Aneurysms
When patients with AAA undergo noncardiac surgery, they should be carefully observed for rupture of aortic aneurysm, embolism due to mural thrombi, and blood coagulation disorder during the perioperative period. It is believed that noncardiac surgery before aneurysm surgery does not significantly increase the incidence of rupture. The indication for AAA surgery should be determined primarily without considering possible effects of noncardiac surgery, and the order of noncardiac surgery and AAA surgery should be based on the prognosis of AAA and noncardiac disease. Physicians should avoid performing gastrointestinal tract surgery and AAA surgery simultaneously since vascular grafts may be contaminated during surgery.

In cases of spindle-shaped aneurysms ≥6 cm in diameter, which are known to have a high risk of rupture, and of saccular aneurysms, symptomatic aneurysms, and infectious aneurysms regardless of the diameter, AAA surgery should be performed before noncardiac surgery or simultaneously with it. Although it has been reported that peripheral arterial embolism develops in 3 to 29\% of patients with AAA,\textsuperscript{78-80}
prediction of embolism is difficult. Patients with echymoses and prolonged hemostasis should be suspected to have consumption coagulopathy associated with aneurysms. The incidence of coagulopathy tends to be high in patients with large aneurysms, and it is difficult to control blood coagulation unless the aneurysm is surgically treated.

Patients with the following anatomical characteristics may undergo stent grafting for the treatment of AAA, and may thus undergo noncardiac surgery earlier than those undergoing conventional aneurysm surgery.

1. A 20 to 22 Fr catheter sheath may be inserted.
2. Infrarenal abdominal aorta (central landing zone) is 19 to 26 mm in diameter and ≥15 mm in length.
3. Infrarenal abdominal aorta with an angle of ≤60° relative to long axis of aneurysm.
4. Common iliac artery (distal landing zone) is 8 to 16 mm in diameter and ≥10 mm in length.
5. Absence of bilateral common iliac aneurysms.

**2) Carotid Artery Stenosis**
The carotid artery should be checked in patients with a history of cerebral infarction and those suspected to be experiencing a transient ischemic attack (TIA). Patients with carotid artery stenosis are at risk for cerebral infarction during the perioperative period of noncardiac surgery. Since the risk of cerebral infarction is high in males, patients with a history of cerebral infarction rather than TIA, patients with cerebral hemisphere signs and symptoms rather than amaurosis, carotid surgery should be considered. No benefit of carotid surgery has been observed in patients with mild stenosis with or without symptoms. Carotid endovascular treatment may be considered in patients with symptomatic severe carotid artery stenosis, those in whom the surgical approach to the carotid artery is difficult, those with a high risks associated with surgery, those with carotid artery stenosis after radiotherapy, and those with carotid artery restenosis after surgery. When noncardiac surgery is performed without treating carotid artery stenosis, patients should be managed carefully to prevent dehydration and hypotension and thus prevent cerebral infarction.

**3) Arteriosclerosis Obliterans of the Lower Extremities**
Acute exacerbation of hemodynamics of the lower extremities is an important problem during the perioperative period of noncardiac surgery. Careful monitoring should be performed, particularly in patients with severe chronic leg ischemia whose blood pressure is of ≤50 to 70 mmHg in the foot joint and ≤50 to 50 mmHg in the toes. When acute ASO of the lower extremity develops, amputation of the lower extremities may be required, or reperfusion injury followed by multi-organ failure may occur.

### 7. Pulmonary Artery Disease

Primary pulmonary artery disease that can coexist in patients undergoing noncardiac surgery are mainly idiopathic PH, familial PH, and chronic pulmonary thromboembolism, and these entities are discussed here. When the following findings are noted in patients planned to undergo noncardiac surgery, they should be suspected to have PH and carefully evaluated for it.

**Clinical findings:** Exertional dyspnea, leg edema, facial edema

**Auscultation:** Pulmonary diastolic murmur and apical holosystolic murmur

**Chest X-ray:** Left second arc protrusion and decrease in peripheral vessel shadow, left fourth arc protrusion

**ECG:** Findings of right ventricular overload (S1Q3T3 and S1S2S3 patterns in typical cases)

**Echocardiography:** Right ventricular enlargement, paradoxical motion of the interventricular septum

Pulmonary artery disease is strongly suspected when resting mean pulmonary arterial pressure in catherization is ≥25 mmHg, and hypocapnia with hypoxemia are observed on arterial blood gas analysis, while no significant pulmonary parenchyma diseases or airway disorders are observed on respiratory function testing. Prior to noncardiac surgery, physicians should consider that the natural history of moderate or severe PH is quite poor.

No systematic criteria are available to evaluate the risk of perioperative complications in noncardiac surgery in patients with PH. Since patients with PH tend to have hypoxemia and
right heart failure, careful monitoring (ECG, arterial line placement, and pulse oximetry) should be performed from the induction of anesthesia through the postoperative period. Although pulmonary arterial catheterization provides important information, it is difficult to place the catheter at an appropriate position, and lung injuries due to puncture and vessel injuries due to balloon dilatation may cause serious outcomes. Transesophageal echocardiography is very useful for monitoring the right ventricular function.

The effects of decreasing pulmonary vascular resistance during the perioperative period of noncardiac surgery with inhaled nitric oxide, dipyridamole, phosphodiesterase (PDE) III inhibitors, PGE, calcium blockers, and intravenous nitroglycerin have been reported. Endothelin-1 receptor antagonist are effective but not appropriate during the perioperative period, since only oral forms of them are available.

8. Idiopathic Cardiomyopathy

Cardiomyopathy is defined as “heart muscle disease associated with cardiac dysfunction”, and is classified into dilated cardiomyopathy, hypertrophic cardiomyopathy, restrictive cardiomyopathy, arrhythmogenic right ventricular cardiomyopathy, and other unclassifiable cardiomyopathy. “Heart muscle disease with known etiology or clearly related to systemic disease” is defined as specific cardiomyopathy, and is not included into the above classification. Although new classification have recently been proposed, this classification is still common in Japan and useful in the clinical setting. Figure 4 shows a flow chart of preoperative examinations for cardiomyopathy.

In management during the perioperative period of noncardiac surgery, arrhythmia and low cardiac output require special attention in patients with any type of cardiomyopathy. Extra vigilance is needed in patients with severe ventricular arrhythmia, which may cause sudden death. Patients often have been treated with antiarrhythmic drugs and may receive continuous intravenous lidocaine infusion during the perioperative period as needed, and many cases of arrhythmia are intractable. It is important to maintain normal sinus rhythm by adjusting electrolyte levels. If such treatment is impossible, heart rate should be controlled while in atrial fibrillation.

Low cardiac output in patients with dilated cardiomyopathy is treated by decreasing afterload with vasodilators and increasing cardiac contractile force with catecholamines and PDE III inhibitors, while such treatment is contraindicated in patients with hypertrophic cardiomyopathy and should be performed with care in patients with restrictive cardiomyopathy. Physicians should attempt to optimize intravascular volume to increase cardiac output regardless of the type of cardiomyopathy. However, since the range of the target intravascular volume is narrow, a pulmonary artery catheter should be placed to monitor hemodynamics carefully during the perioperative period, in which intravascular volume may change significantly, and diuretics should be administered whenever necessary. Patients who had received warfarin to prevent embolism should be switched from warfarin to continuous infusion of heparin at least two days before surgery, and should discontinue heparin therapy about 3 hours before surgery. It is preferable that warfarin therapy be promptly resumed when the risk of postoperative bleeding has decreased, and that patients who cannot take drugs orally be administered heparin continuously. Adequate pain control is necessary, since postoperative pain increases afterload by increasing sympathetic activity.

9. Arrhythmias

In addition to myocardial infarction, arrhythmias and conduction disorders are quite common perioperative cardiac complications of noncardiac surgery. Arrhythmia may not occur as a single disorder. It is important to check for all possible heart diseases associated with arrhythmia when examining patients with perioperative arrhythmia.

(1) Perioperative Arrhythmia and Its Treatment
i) Preoperative Arrhythmia
When arrhythmia occurs in patients planned to undergo noncardiac surgery, physicians should check for the presence/absence of an underlying disease causing the arrhythmia and consider how to manage the patient should arrhythmia worsen during the perioperative period. The following types of organic heart disease may play roles in preoperative arrhythmia.
- Sick sinus syndrome, atrioventricular block (particularly Mobitz type II, Grade 3) → Coronary heart disease
- Ventricular extrasystole (multifocal, sequential) → Coronary heart disease, previous myocardial infarction
- Ventricular extrasystole → Cardiomyopathy, left ventricular hypertrophy/dilatation (valvular disease)
- Atrial fibrillation → Left ventricular diastolic dysfunction, valvular disease

There are reports suggesting that detailed monitoring and specific treatment are unnecessary in patients with preoperative ventricular extrasystole when myocardial infarction or other heart disease is absent. However, since arrhythmia may worsen during the perioperative period in patients with ischemic heart disease, appropriate examination should be performed to exclude possible diseases and uncover undiagnosed diseases.

For patients who have been diagnosed with arrhythmia and are taking antiarrhythmic drugs, physicians should consult with anesthesiologists to determine whether antiarrhythmic drugs should be given intravenously or be suspended during the perioperative period. Many believe that β blockers used before surgery should be continued during the perioperative period. In patients receiving anticoagulation therapy to control atrial fibrillation, physicians should consider the benefits and risks of bleeding with anticoagulation therapy in determining a strategy for treatment of the perioperative period.

### ii) Arrhythmias That May Occur During Surgery

Table 16 lists conditions that may cause arrhythmias during the perioperative period. Although arrhythmias existing before surgery and underlying heart disease affect the type and incidence of arrhythmias during surgery, myocardial ischemia, overload on the heart, hypokalemia, and hypomagnesemia during surgery may induce arrhythmia. Anesthetics, surgical procedures, and bleeding control also affect the incidence of arrhythmia during surgery. Since cardiac arrest may occur at the time of reperfusion during surgical treatment of intestinal ischemia or lower extremity ischemia, appropriate measures such as exsanguination of venous blood may be required.

Intraoperative bradycardia may be improved for a short period of time with atropine sulfate and β agonists. However, when bradycardia is prolonged or severe, patients may need ventricular pacing using transvenous leads inserted from the internal jugular vein, transesophageal pacing, or external pacing using chest patch electrodes.

### iii) Arrhythmias That May Occur After Surgery

The incidence of cardiac complications is highest during the first several days after surgery. Arrhythmias that may occur after surgery include those immediately after recovery from anesthesia, fatal arrhythmias due to pulmonary embolism, which is prone to occur during the first several days after surgery, and atrial fibrillation, the incidence of which is high during the first week after surgery.

Atrial fibrillation is clinically significant, since thrombus may develop in the left atrium and cause arterial embolism. Transesophageal echocardiography is useful arterial to exclude possible arterial thrombus. Patients with atrial fibrillation may exhibit severe bradycardia requiring temporary pacing. Since severe and prolonged bradycardia may reflect the presence of latent conduction disorder, physicians should consider prompt implantation of permanent pacemakers.

### (2) Perioperative Management of Patients Using Implantable Pacemakers and Implantable Cardioverter Defibrillators

In patients with implantable pacemakers and implantable cardioverter defibrillators (ICD), electromagnetic interference and infection are the most important complications of noncardiac surgery.

The use of electric knives may interfere with pacemakers, which will then not function properly. Unipolar devices are more susceptible to interference than bipolar devices. Physicians should be aware of the risk of electromagnetic interference when the surgical site is in close proximity to the pacemaker or leads. Physicians should also be familiar with the possible effects of use of electric knives at a surgical site distant from the pacemaker. Use of bipolar electric knives is in all cases the safest procedure, though such devices may make surgical procedures more complicated than unipolar devices. Pacing mode must be adjusted during surgery if surgical site is close near to the pacemaker and require frequent use of electric knives to stop bleeding. In patients who depend on a pacemaker to maintain heart rate, AOO, VOO, or DOO mode may be used during surgery. In patients in their own rhythm with the pacemaker in sense mode, the pacemaker is not used or is used with a low pacing rate during surgery.

In patients using an ICD, electromagnetic interference by electric knives may trigger the device, which may deliver a shock during surgery. In such patients, external patch electrodes should be placed on the chest wall to prepare for prompt electrocardioversion, and the ICD should be turned off during surgery. After surgery, the ICD should promptly be turned on. Continuous administration of antiarrhythmic drugs should be considered in patients susceptible to ventricular tachycardia. In any case, physicians and medical engineers with expertise in adjusting programs of implantable pacemakers and ICD should support the surgery.

In patients undergoing gastrointestinal surgery and patients with traumatic open wounds, bacteremia may develop. If leads exposed to venous blood become infected, the pacemaker may need to be removed. In patients with implantable pacemakers and ICD, antibiotic treatment should be initiated during surgery to minimize the occurrence of pacemaker infection.


Appendix

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