Section 1 Routine Cardiac Surgery

Chapter 1

Basic Principles of Cardiac Surgery

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The art of surgery involves doing everything
as gracefully and efficiently as possible

Denton Arthur Cooley (1920–2016)

Cardiac surgery has made extraordinary progress in the last few decades. This is largely the result of dedicated effort and almost perfect teamwork among cardiac surgeons and the allied specialty groups (anaesthesists are obviously part of it). The creativity, imagination and skills that have given rise to numerous technical innovations and surgical procedures have brought to reality the surgical treatment of the majority of the congenital malformations and the acquired lesions of the heart. The basic principles of patient selection and surgical technique in current adult cardiac surgical practice are outlined below.

Patient Selection

It is debatable whether there is such a thing as 'patient selection'. Doctors do not have a treatment in their pocket for which they select patients: they have patients for whom they should select the best treatment. Be that as it may, for any medical treatment to be of use, it should provide one of two things: it should either improve the symptoms or improve the prognosis. The decision to proceed with a cardiac operation is therefore based on weighing the advantages (as indicated on symptomatic or prognostic grounds or both) against the main disadvantage, which is the risk of the operation.

The symptomatic indication is always the same whatever the surgery: the failure of medical treatment adequately to control the symptoms.

Prognostic indications are a little more complicated and differ between the various cardiac conditions. Some lesions have such an obvious impact on prognosis that the surgical option is virtually mandatory unless the risk is truly prohibitive. An example would be acute aortic dissection involving the ascending aorta. This carries a cumulative mortality of 1% for every hour of conservative treatment, so that by two days nearly half the patients would have expired. Luckily, most cardiac conditions are not like that, and the risk of conservative management needs to be assessed carefully and weighed against the risk of surgery. In some areas that information is still poorly defined, but in others there are clear guidelines based on quite good evidence. Some of these are outlined below.

Ischaemic Heart Disease

The evidence for IHD comes from two aging but still valid studies carried out first in America and then in Europe, where patients with angina were randomized to either medical treatment or surgical treatment. With passing time, those treated surgically began to show a survival advantage. This was particularly marked in the groups shown in Table 1.1, listed in descending order of greater prognostic importance.

Table 1.1 Prognostic impact of CABG surgery

Survival benefit	Indication
+++	>50% stenosis of the main stem of the left coronary artery (LMS)
++	Proximal stenosis of the three major coronary arteries: LAD, circumflex and right coronary arteries
+	>50% stenosis of two major coronary arteries including high-grade stenosis of the proximal LAD

It can be seen from the above that coronary angiography is essential to assess the prognostic implications of IHD, and makes decision-making relatively straightforward. On prognostic grounds alone, a young, otherwise fit, patient with a 90% LMS stenosis should be offered surgery, whereas an old, unfit diabetic arteriopath with single vessel disease affecting only a branch of the circumflex coronary artery should not.

Valve Disease

The symptomatic indication is the same as everywhere else: failure of medical treatment adequately to control the symptoms. The prognostic indication in general depends on the valve lesion, the presence of symptoms and changes in the structure and function of the heart (abnormal shape and increased size of the ventricle, ventricular function and AF are markers of an advanced stage of the valve pathology). In other words, regardless of the severity of the stenosis or regurgitation, there is no prognostic indication if the patient is asymptomatic with normal heart function and dimensions.

Risk Assessment

The mortality of cardiac surgery has for over 40 years been measured and incorporated into decisions about clinical care. Crude mortality, however, is not enough, and even journalists understand that the risk profile of the patient has as much to do with outcome as the quality of surgical care that is given.

Many models of risk in adult cardiac surgery have been developed, but the authors of this chapter are particularly (and understandably) biased toward the European System for Cardiac Operative Risk Evaluation (EuroSCORE). This was originally developed in 1999 and rapidly became the most widely used risk model in cardiac surgery. The EuroSCORE originated from the analysis of data of more than 13,000 consecutive cases performed in more than 100 European centres in 1995. Progress in surgical techniques and postoperative care made the original data set outdated and led to the development of a new model: the EuroSCORE-II. The core of risk factors is almost the same although some definitions are more precise. These variables include patient-related factors (age, gender, lung disease, renal impairment, extracardiac arteriopathy, poor mobility, previous cardiac surgery, active endocarditis, critical preoperative state, DM on insulin), cardiac-related factors (functional class, recent MI, LV function, PHT) and operative-related factors (priority, weight of surgical procedure, surgery on the thoracic aorta). The EuroSCORE calculator is available online.

Operative Principles

Setting Up

Most cardiac operations are carried out with a standard set-up, which follows the patient surgical safety checklists. Once key factors associated with reduction of postoperative morbidity and mortality such as timely antibiotic administration, acknowledgement of allergies, blood availability and sterility have been verified, surgery begins.

Median sternotomy is the preferred access for most cardiac operations. Before dividing the sternum, it is useful to deflate the lungs to mitigate the risk of opening the pleural cavities. This minor event can be easily treated by placing a drain in the opened pleura, but in patients with reduced respiratory reserve it can be beneficial to keep the pleural intact. If the procedure includes the coronary surgery (CABG) the next step will be conduit harvesting (usually the left internal mammary artery (LIMA) and long saphenous vein (LSV). The LIMA is a precious conduit in coronary surgery: it is an ideal graft to the LAD coronary artery, which stays patent virtually forever and seems immune to atherosclerosis. If required, a segment of the LSV is harvested simultaneously. Once this part of the set-up is complete, the patient is fully heparinized and the ACT used to confirm the adequacy of anticoagulation. Cannulation of the ascending aorta and RA will follow. A double purse-string suture is used to secure the aortic cannulation site and further purse-string sutures are placed in the RA to secure the venous cannula or cannulae, which drain blood into the heart–lung machine. Another purse-string suture will be placed lower in the ascending aorta for the cardioplegia line, which will be essential to stop and intermittently perfuse the heart during the 'cross-clamp time'. Additional cannulation sites can be the right superior pulmonary vein for the LV vent insertion, the RA for the retrograde cardioplegia cannula or the PA for further venting. Venting the heart chambers and great vessels provide a relaxing bloodless field, which is an important aspect of a good set-up. Once everybody is happy with the ACT and the conduits are ready, the patient is 'put on bypass': blood is drained from the RA into the oxygenator, by simple gravity or vacuum-assisted. Oxygenated blood is then pumped into the aorta and the ventilator is switched off.

Myocardial Protection

During the central part of the operation, the aorta is clamped between the site of insertion of the aortic cannula and the origin of the coronary arteries. This produces a bloodless field, and makes intricate surgery possible, but during that time the heart will be ischaemic and will need protection.

The strategies used to minimize the ischaemic insult rely on the reduction of the myocardial metabolism and oxygen consumption by cooling the heart and achieving cardiac arrest, and this is achieved by infusing a 'cardioplegic' solution into the coronary arteries. The combination of cooling and cardiac arrest can reduce the myocardial oxygen consumption by more than 95%. There is no fixed time for delivering the cardioplegic solution during the operation but usually this is done every 15–20 minutes. Be aware that long cross-clamp time can be tolerated with an appropriate myocardial protection, which implies meticulous administration of regular doses of cardioplegia. On the other hand, if the surgeon's strategy for saving time is to skip the myocardial protection cardioplegia, the price to pay when the cross-clamp is released could be high, with a globally ischaemic heart and the need of pharmacological or mechanical support.

Coronary Surgery

The standard triple bypass (for triple vessel disease) involves the use of the LIMA and two segments of LSV. The LIMA is routinely anastomosed to the LAD coronary artery. The LIMA-to-LAD graft is considered a major quality indicator in coronary surgery and is associated with high long-term patency rates. Total arterial revascularization (using also the right mammary or radial arteries) might be beneficial in younger patients since the long-term patency of the vein graft is not ideal. Pooled analysis of observational studies suggests that, at 10 years, there are better outcomes with bilateral internal mammary grafting than with single internal mammary grafting.

Technically, after the cardioplegia, with the heart arrested and vented through the aortic root, the target coronary artery is opened longitudinally, distally to any stenosis. The coronary anastomosis is then constructed with fine continuous sutures. The time required to perform a coronary anastomosis can be variable according to the coronary artery characteristics and the talent and expertise of the surgeon. It should take between 5 and 15 minutes. Precision is essential and should be prioritized over speed. Additional cardioplegia may be given into the aortic root or via the grafts or both as the case proceeds. The LIMA anastomosis, usually to the LAD, is constructed last.

Aortic Valve Surgery

The aorta is opened above the sinuses of Valsalva. If the patient has moderate to severe AR, cardioplegia must be administered directly into the coronary ostia, which are visible through the open aortotomy, or alternatively in a retrograde fashion (being aware that retrograde cardioplegia mainly acts on the LV for anatomical reasons, therefore the RV is poorly protected when only retrograde cardioplegia is used). Direct administration via the aortic root would simply distend the LV and the raised intraventricular pressure would reduce the effectiveness of the cardioplegic solution. AVR is carried out by removing the diseased valve, inserting sutures first into the annulus then into the sewing ring of the prosthesis, sliding the prosthesis on the sutures down into the annulus and tying the sutures. The aorta is then closed with a continuous suture. The intraoperative TOE is accepted as an essential tool to confirm good positioning and function of the prosthetic valve and to exclude any paravalvular leaks.

Mitral Valve Surgery

Mitral repair involves many different manoeuvres, such as leaflet resection, artificial chords, annular plication or annuloplasty. Most units carrying out mitral repair rely heavily on TOE to analyze the nature of the mitral lesion and to confirm the success of the repair. Mitral repair has better short- and long-term outcome if compared to MVR and, in high volume centres, the rate of repair for degenerative MR may be close to 100%. Replacement follows the same pattern as AVR. Bicaval cannulation is required to decompress the RA and permit access to the LA. Once the mitral repair or replacement is completed, the left atriotomy, which represents the standard access, is closed with a continuous suture.

De-airing

If a main heart chamber (atrium, aorta, PA or ventricle) has been opened as part of the procedure, it is important to evacuate air from the heart, especially the left side, before the heart is put back into the circulation and the air escapes to the brain. This may involve a fair amount of vigorous physical activity by the surgeon while the heart, and sometimes the entire patient, is shaken, stirred and repositioned to optimize the process. This, together with a request for restarting ventilation briefly, to expel air from the pulmonary veins, is usually sufficient to rouse the sleepiest anaesthetist from deepest torpor. It is also a reliable signal that the end, though not quite close enough, is now at least in sight. TOE is useful for detecting residual air and determining the adequacy of de-airing.

Clamp-Off

The AXC is then removed, allowing perfusion of the coronary arteries and the heart then begins to come to life. If myocardial protection has been optimal, the heart often reverts to NSR. If not, VF is the commonest dysrhythmia seen and internal cardioversion is carried out. Any proximal anastomoses (so-called ‘top ends’) of coronary grafts are then carried out using a partially occluding or ‘side-biting’ aortic clamp; alternatively, top ends can be performed with the AXC on, depending on surgeon preference and on the quality of the aorta (multiple aortic clamping seems to be associated to higher incidence of stroke). The patient is then prepared for ‘coming off bypass’. The lungs are ventilated and the perfusionist gradually occludes the RA cannula, thus allowing more blood to return to the heart and be pumped. The arterial pressure line begins to show pulsation as the heart gradually takes over the circulation. The heart–lung machine is then stopped and the atrial or caval cannulae removed. In this phase of the operation some residual air bubbles can embolize into the right coronary artery, which originates in the anterior part of the aortic root (highest point in a supine patient). The typical sign of this fairly common complication is distension of the RV, global (and usually transient) hypokinesia and obviously, hypotension. The expert anaesthetist will promptly recognize this condition. The first manoeuvres consist in increasing the perfusion pressure in order to get rid of the air through the capillary circulation. Calcium chloride and various vasoconstrictors are usually used. If hypotension and low CO do not resolve promptly the next step is to restart the CPB and assist the heart until the RV recovers.

The End

Heparin is reversed using its antidote, protamine, which often produces hypotension. This can be treated by transfusing blood from the pump into the patient via the aortic cannula. Haemostasis is secured (what a long and tedious process these three simple words describe!) and the chest is closed over the appropriate number of drains and epicardial pacing wires. Achieving perfect haemostasis is both a surgical and a medical task. Checking the ACT and bringing it back to the baseline, administering further doses of protamine to treat heparin rebound and the judicious use of blood products are as important as careful attention to surgical bleeding. A patient who bleeds in the postoperative period is exposed to many risks related to haemodynamic instability, surgical re-exploration and transfusion, and faces an overall higher mortality.

Off-Pump Surgery

In an effort to avoid the potential adverse effects of CPB, some surgeons perform coronary surgery without it, using clever contraptions to steady the bit of heart they are working on. There is no cannulation, extracorporeal circulation or cross-clamping of the aorta. Despite the theoretical advantages of avoiding the use of CPB (aortic cannulation and manipulation, inflammatory response), there is still a controversy in its effectiveness and indication. As a result, off-pump surgery is not the first choice in Europe and the United States for routine surgical revascularization. Furthermore, the outcome seems related to the volume of operations performed, since off-pump surgery is a technically challenging exercise for the surgeon. The absence of CPB means that these operations are more demanding of the anaesthetist as well, who will need to work constantly on optimizing haemodynamics as the heart is mobilized, retracted and stabilized while continuing to support the circulation (see Chapter 12). In general, off-pump CABG has fewer early complications but less complete revascularization and possibly less good long-term graft patency.

Minimally Invasive Cardiac Surgery

Efforts to reduce the invasiveness of cardiac surgery continue apace. What is called 'minimally invasive' does not always truly represent a smaller surgical burden for the patient. In minimal invasive mitral surgery, the surgeon performs the same operation through a small right thoracotomy using long instruments and a camera. Peripheral cannulation sites (jugular and femoral vein for venous drainage and femoral artery for the arterial return may be used and a TOE-guided endo-aortic balloon clamp occludes the ascending aorta and delivers cardioplegia). Often, the cross-clamp and bypass time are prolonged because of the increased difficulty of completing the procedure. The patient avoids a full sternotomy but may have a longer procedure. Minimally invasive mitral surgery requires dedicated training and a regular caseload in order to achieve good and consistent results. Some centres offer AVR through a mini-sternotomy (upper third) or a small right thoracotomy. All the above procedures have outcomes that are strongly volume-related. Valve technology has also evolved and sutureless AV prostheses are now available. Transcatheter AV implantation (TAVI) is also developing, and in the UK it is routinely used for patients requiring AVR who are considered unsuitable for conventional surgery. The reader may wish to speculate on the motivation for all these developments at a time when cardiac surgery is phenomenally successful and has an enviable safety record. Are we motivated by a true desire to help the patients by reducing the invasiveness of our procedure, a desperate attempt to claw back from the cardiologists the large number of patients now treated by percutaneous intervention or do surgeons, like little children, get bored with their predictable old 'toys' and want new ones?

Key Points

- Surgery is indicated on symptomatic grounds when symptoms are not adequately controlled by maximal medical therapy.
- Surgery is indicated on prognostic grounds in situations such as aortic dissection and LMS coronary disease, regardless of the severity of symptoms.
- The use of validated risk models, such as EuroSCORE-II, allows rapid risk assessment at the point of care and helps the surgeon in the decision-making process.
- Most routine cardiac surgical procedures follow a predictable and well-defined path.
- Myocardial protection and surgical accuracy are cornerstones of modern cardiac surgery.
- Haemostasis is the result of medical and surgical efforts.

Further Reading

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