Redo Valve Surgery—Current Status and Future Perspectives

Hiroshi Furukawa, MD, PhD and Kazuo Tanemoto, MD, PhD

Surgeons are now facing the challenge of redo valve surgery because of the increasing number of elderly individuals in Japan. The incidence of bioprosthesis dysfunction has increased among the various surgical indications of redo valve surgery due to the preference of patients and a paradigm shift in prostheses from mechanical valves to bioprostheses. Previous studies reported that the clinical outcomes of reoperative valvular surgery have markedly improved due to the maneuver of myocardial protection, cardiopulmonary bypass strategies, and appropriate safer surgical approach. The general surgical outcomes of redo valve surgery have been reported as being similar to those of primary valve surgery; however, this is still controversial and has not yet been confirmed in some developed countries. Although the unique surgical technique of transcatheter valve-in-valve implantation for bioprosthetic dysfunction is promising, redo valve surgery may become more prevalent in the future. We here reviewed the current status of reoperative valve surgery and future perspectives including catheter-based surgical interventions.

Keywords: redo valve surgery, resternotomy, elderly patients, transcatheter valve implantation, valve-in-valve

Introduction

Improvements in surgical techniques and a prolonged life expectancy in the current population have increased the frequency of redo heart valve surgery. Following the current guidelines for the management of patients with valvular heart disease and the preference of patients to avoid lifelong anticoagulation therapy, a paradigm shift in prosthesis selection from mechanical valves to bioprostheses may occur worldwide. The choice of the prostheses should be adapted to each patient depending on age, life expectancy, valve size, and cardiac as well as extra-cardiac co-morbidities. Cardiac surgeons frequently face the challenge of deciding whether a mechanical or bioprosthetic valve is more appropriate for the individual patient. According to the Society of Thoracic Surgeons National Database report, the use of bioprostheses increased to 78.4% of the total number of valve implantations performed between 1997 and 2006 in the United States, with similar findings been reported in European countries and Japan. The number of redo valve surgeries has been increasing in Japan, with over one thousand being performed each year, and a gradual decrease in mortality to an acceptable 7% to 10% was described in an annual report of the Japanese Association for Thoracic Surgery. The unique surgical technique of transcatheter valve-in-valve implantation for bioprosthetic dysfunction is promising, redo valve surgery may become more prevalent in the future. We here reviewed the current status of reoperative valve surgery and future perspectives including catheter-based surgical interventions.
Surgical Indication and Risk Analysis

The surgical indication for redo valvular surgery has generally been well-defined by previous studies. The five classifications of surgical indication for redo valvular surgery are as follows: (1) failed repair/new native valve disease, (2) prosthetic valve dysfunction, (3) prosthetic valve leaks (PVLs), (4) valve thrombosis, and (5) prosthetic valve endocarditis (PVE). The structural degeneration of bioprostheses is the leading cause and most frequent indication for reoperation in patients with bioprosthetic valves. PVLs are the most common cause of non-structural dysfunction following valve replacements. The risk of valve re-replacement was analyzed in 640 patients in a large-scale study, and the overall operative mortality was shown to improve with each passing year.

The most common indications for redo aortic valve replacement (AVR) are bioprosthetic structural valve degeneration, PVE, PVLs, and thrombosis or pannus formation in mechanical aortic valves. While pannus is common to both biological and mechanical valves, acute prosthetic thrombosis is a complication that is mostly associated with mechanical valves. The operative risk of thrombosis is higher than that of pannus, and even bileaflet prostheses are less prone to this complication than monoleaflet mechanical valves. Another large study of one thousand consecutive cardiac reoperations for valve surgery in 897 patients showed the predictors of increased risk for first aortic valve reoperation, which is likely to be advanced age, endocarditis, female gender, left ventricular dysfunction, and the number of coronary artery diseases. And also they indicated the predictors for first mitral valve reoperation, which were elderly patients, clinical status such as preoperative shock or cardiac arrest, previous aortic or tricuspid valve surgery, type of mitral valve procedure, and left ventricular dysfunction. Among these risk factors, they argued that the most consistent predictor of risk for patients undergoing valve reoperations was advanced age.

The operative risk for patients undergoing redo valvular operations has been markedly reduced due to improvements in myocardial protection and cardiopulmonary bypass (CPB) strategies. Luciani and colleagues reported that in-hospital mortality was 3.8%, and overall mortality at the end of a 30-month follow-up was 9.3%. They also indicated that the predictors of mortality in patients who underwent redo surgery. They showed that an advanced New York Heart Association (NYHA) class, advanced age, lower ejection fraction, emergent or urgent surgery, renal dysfunction, and concomitant tricuspid valvular disease were significant predictors of mortality.

Cohn summarized the clinical evolution of redo cardiac surgery, and revealed that the main reasons to improve the clinical outcomes of redo cardiac surgery were following categories; (1) early referral for prosthetic dysfunction, (2) alternative approaches to prevent injury to adherent cardiac structures, (3) alternative perfusion sites, (4) improved hemostasis during surgery, (5) alternative techniques for reoperation after CABG and thoracic aortic surgery.

Surgical Approach

Controversy surrounds the surgical approach for redo valve surgery. Resternotomy is the standard approach for reentry and re-exposure of the reoperative surgical field. However, bleeding and injury to the cardiac structures and previously placed coronary artery bypass grafts could result in hemodynamic compromise. This catastrophic hemorrhage during redo sternotomy is the most important issue for the management of redo valve surgery. A previous study reported that 88% of hemorrhage occurred when the pericardium had not been closed in the first surgery, and recommended that groin preparation and medical records including previous surgical records should be checked preoperatively to obtain a safer approach for high-risk patients.
Many recent studies have indicated that the number of previous sternotomies does not increase the risk of reentry injuries to the heart and great vessels, with a life-threatening injury only being reported in 7% to 9% of patients during reoperation. Direct vision resternotomy has been associated with zero, moderate, or major cardiac injury/catastrophic hemorrhage during reoperation. A change to the surgical technique to include minimal dissection of the heart has contributed to shorter aortic cross clamping and CPB times. Improvements in cardiac anesthesia and postoperative care appeared to have been beneficial for all cardiac reoperations.

Preoperative computed tomography (CT) scanning should be performed to visualize the relationship between the mediastinal contents and the sternum and identify patients at risk of injury during reentry. The 3D CT imaging technique is also useful for defining the optimal surgical strategy for redo cardiac surgery. Preoperative CT visualization has recently become mandatory to confirm a safe surgical plan for redo cardiac surgery.

Redo Aortic Valve Replacement

Reoperations on aortic valves are associated with increased mortality, which may affect valve prosthesis selection at the time of initial AVR. Of 298 reoperations performed, mortality was 4.6% for redo AVR, and was 2.3% for the primary surgery. The elective replacement of malfunctioning aortic bioprostheses can be performed with results being equal to the primary surgery. These findings support the expanded use of bioprosthetic valves in younger patients. A result of a recent study showed that the use of a bioprosthesis in young patients for first-time AVR was associated with a higher reoperation risk than the use of a mechanical valve, but not with an increase in long-term mortality. The mortality of redo AVR in Japan has decreased to 7%—9%, however, this is still higher in than that of the primary surgery, which is approximately 3%. These findings do not support the results of many previous studies, in which the mortality of redo AVR was comparable to that of the primary surgery in other developed countries. (Fig. 2).

Pannus is one of the causes of reoperation in patients with mechanical prostheses. Sakamoto, et al. indicated that the small bileaflet mechanical valves may promote pannus formation; therefore, the larger valve implantation may contribute to a reduction of pannus formation. Teshima and colleagues suggested that the mechanism of pannus formation originated from the neointima of the periannulus structures of the left ventricular septum.

Minimally invasive redo AVR has been performed with acceptable operative mortality. The main advantages of minimally invasive approach for redo AVR such as via mini-thoracotomy and partial upper hemi-sternotomy were a shorter hospital length of stay and less blood product requirements. Consistent with the minimally invasive approach for redo AVR, valve-in-valve (VinV) AVR may be an alternative and promising option for surgery in the future.

Redo Mitral Valve Replacement

A concomitant increase in the incidence of redo mitral valve replacement (MVR) may be observed with improvements in long-term survival following mitral valve surgery. The incidence of redo mitral valve surgical procedures is increasing, and currently accounts for more than 10% of all mitral valve surgeries in the United States. With careful planning and execution, the outcomes for redo mitral valve surgeries in contemporary practice are favorable and identical to those of primary surgeries. The mortality of redo MVR in Japan has consistently been 6%—10%, with the hospital deaths from the primary operation gradually increasing. (Fig. 3). These findings increased mortality of initial MVR operation could be due to the prevalence of mitral valve repair in low risk patients.
A large-scale study of 744 patients among 11908 mitral valve surgeries revealed that the reasons for reoperation were mainly the progression of lesions following valve thrombosis and endocarditis.38) Redo mitral valve surgery is safe and can be performed with an acceptable mortality of 4.2%–5.6%.38,39) The indication of redo MVR was shown to be structural dysfunction, PVLs, nonstructural dysfunction, PVE and the progression of other native valve diseases.40) The risk of redo MVR is low, which suggests that there should be less reluctance to recommend a bioprosthesis over a mechanical prosthesis to patients.41)

Another novel approach to use right anterolateral thoracotomy without aortic or right atrial cannulation and without aortic cross-clamping or cardioplegia instead of cardioplegia may be favorable.42) A recent study of 134 patients who underwent redo MVR with ventricular fibrillation, and 316 patients who underwent beating heart surgery, revealed that the 30-day mortality was similar for both (7.4% for ventricular fibrillation and 6.5% for beating heart). Redo right thoracotomy mitral valve surgery on the beating heart is associated with a shorter CPB time, less transfusion requirements, shorter postoperative ventilation, and lower mortality.43) Right thoracotomy is an alternative route that has been previously used to access the mitral valve in the earlier years of cardiac surgery, and offers the advantage of a fresh surgical field in the context of redo surgery. Redo MVR via right thoracotomy on the beating heart under normothermic bypass offers a safe alternative to redo median sternotomy in this high-risk group. Complication rates are low and perioperative mortality was shown to be lower than that generally reported with conventional surgery.44)

Minimally invasive mitral valve reoperations, which were performed in 181 consecutive patients by right-sided lateral minithoracotomy with femoral cannulation for CPB is a useful alternative for patients requiring a mitral valve procedure after previous cardiac surgery, particularly in patients with patent coronary bypass grafts or previous AVR.45) Port-access video-assisted right mini-thoracotomy also allows for good results in a difficult subset of patients.46) The video-assisted minimal access correction of atrioventricular valve disease following previous cardiac surgery is not only feasible, but had lower than predicted mortality and strong patient satisfaction; however, this procedure is challenging.47) Relative contraindications for this technique include severe left ventricular hypertrophy, inability to perform transesophageal echocardiography, moderate to severe aortic valve insufficiency, severe peripheral arterial disease, inability to place pulmonary artery catheter, severe chronic obstructive pulmonary disease, and “hostile” right chest.48)

Redo Valve Surgery Following Previous Coronary Artery Bypass Grafting and Cardioprotective Maneuver

An injury to patent coronary artery bypass grafts, especially internal mammary artery (IMA) grafts, during reoperation via resternotomy may be fatal and is associated with high mortality. A patent IMA graft as an independent predictor of intraoperative injury during redo cardiac procedures, and intraoperative injury has been associated with a higher rate of perioperative mortality.25) The early mortality of redo AVR following coronary artery bypass grafting (CABG) was shown to be 14%, with late mortality being 17%. Although early morbidity and mortality were high, the long-term outcomes of the surviving patients were favorable.49) The prevalence, outcomes, and operative strategies of patients with an injury to a patent left IMA graft to the left anterior descending (LAD) at coronary reoperation were described by Gillinov and coworkers. They concluded that (1) the prevalence of an injury to a patent left IMA graft was 5.3%; (2) various techniques could be used to restore blood flow to the LAD; and (3) ineffective revascularization of the LAD was associated with operative mortality.50) On the other
Redo Valve Surgery in Elderly Patients

As elderly populations in developed countries continue to expand rapidly, interest in the outcomes of redo cardiac surgery on this group of patients has increased. An increasing number of elderly patients are being referred for repeat surgical interventions for valvular heart disease. Based on clinical results showing 6.8%–10.0% overall mortality in patients with redo valvular surgery,16,18,55) redo valvular surgery can be performed in an elderly cohort with acceptable morbidity and mortality.56) These results suggest that advanced age and the need for reoperation is not a contraindication to conventional surgical interventions.

In contrast, Kirsch and associates reported poor outcomes; hospital mortality was 32% and cardiac reoperations for valvular heart disease in octogenarians carried a high risk of postoperative morbidity and mortality.57) Balsam and colleagues reported that hospital mortality was 13.8% in 363 patients aged 75 years or more who underwent isolated redo valve surgery, and 12.8% and 15.1% for aortic and mitral valve surgeries, respectively. Multivariable predictors of hospital death were NYHA functional class III or IV heart failure, dialysis, and more than one reoperation.58) Eitz and coworkers reported an acceptable outcome of redo AVR in octogenarians, and the operative mortality was 16.4%.59) Surgical indication may increase in elderly patients due to the future prevalence of transcatheter VinV implantation.

Valve-in-Valve for Failed Aortic Bioprosthesis

A rapid increase in the use of transcatheter heart valve implantation to treat high-risk patients with severe aortic stenosis has been observed in European countries. The recent early and midterm results of transcatheter aortic valve implantation are promising and may represent an alternative to surgical AVR in high-risk patients.

Walther and colleagues reported the first human VinV implantation for a failed aortic bioprosthesis by using an Edwards Sapien valve60) and Wenaweser, et al. implanted a CoreValve THV within an aortic Mitroflow surgical valve using a transarterial approach with excellent functional outcomes after 1 year.61) Kempfert and associates has developed the off-pump beating heart concept of transapical aortic valve implantation using the VinV concept, especially in high risk elderly patients.62) Transcatheter VinV is a reproducible option for the management of bioprosthetic valve failure.63) This VinV strategy may reduce the frequency of ventricular embolization in the first transcatheter valve, which may have required urgent sternotomy in a patient who is otherwise denied for conventional AVR.64) As mentioned above, the VinV procedure might be a promising maneuver for high-risk redo patients, and preliminary studies reported by Ferrari showed the acceptable clinical results, which is the absence of PVLs, transvalvular gradients, and low rates of perioperative complication. However, this procedure might be related to size mismatches and accurate positioning within the degenerated bioprosthesis, in case of VinV in a 21-mm bioprosthesis.65) Therefore, surgeons should implant larger prostheses in the primary surgery based on further consideration of the VinV concept.

Valve-in-Valve for Mitral Bioprosthesis Dysfunction

Because operative mortality and morbidity associated with redo mitral surgery remain high, as described previously, the VinV concept for mitral bioprosthesis dysfunction has been increasing considered, but still remains challenging. Cheung, et al. reported the first human case of transapical transcatheter mitral valve implantation with a 26-mm Cribier-Edwards transcatheter valve into the failed mitral bioprosthetic valve of an elderly man with multiple comorbidities.66) They also described successful transapical transcatheter mitral VinV implantation in 11 patients with no 30-day mortality. Transapical...
Furukawa H, et al.

transcatheter mitral VinV implantation may offer an alternate and safer approach for high-risk patients.\(^{65}\) Wilbring and colleagues described 7 patients who underwent successful transapical mitral VinV implantation, in which Edwards SAPIEN valves of 26- and 29-mm in size were implanted.\(^{66}\) Seiffert and coworkers reported the efficacy of transapical mitral VinV implantations in six patients. With acceptable results in a high-risk population, transapical mitral VinV implantation can be considered as a complementary approach to redo mitral valve surgery in select patients.\(^{69}\) Cerillo and colleagues reported that the mitral and tricuspid VinV in the preliminary experiences. They showed that this approach may eliminate the need for CPB and cardioplegic arrest, which can consistently increase the surgical indication for high risk patients.\(^{70}\)

**Perioperative Management**

Tranexamic acid (TA) and aprotinin have been used for perioperative hemostatic management. In previous literatures by Shore-Lesserson, et al. indicated that TA administration prior to CPB might reduce the postoperative transfusion and bleeding.\(^{71}\) Aprotinin is another modality for management of perioperative hemostasis. Rodrigues and coworkers showed the efficacy and safety of aprotinin administration were similar to those of primary valve surgery without aprotinin.\(^{72}\) Aprotinin recipients benefited from a significant reduction in bleeding complications, and lower perioperative and in-hospital mortalities than those of untreated patients, in which ana-phylactic reactions and clinically significant thromboembolic events were not observed.\(^{73}\) TA and aprotinin are both effective in reducing intraoperative and postoperative blood loss and the need for blood product transfusions by patients undergoing redo cardiac valve surgery.\(^{74}\)

The aggressive use of fibrin sealant for redo valvular surgery is another strategy used to reduce intraoperative bleeding. Fibrin sealant is safe and highly effective at controlling localized bleeding in cardiac reoperations. Fibrin sealant reduces postoperative blood loss and decreases the incidence of emergency resternotomy. These findings indicate that fibrin sealant is a valuable hemostatic agent in redo cardiac surgery.\(^{75,76}\)

For dissecting the mediastinal adhesive structures during redo surgery, the harmonic scalpel was likely to achieve optimal tissue dissection with little blood loss. Luciani et al. reported that the efficacy of harmonic scalpel was markedly reduced postoperative bleeding, lower incidence of minor complications, cardiac injuries, and major arrhythmias, and less need for transfusions in redo cardiac surgery.\(^{77}\)

**Future Perspectives**

Because of greater life expectancies, a concomitantly increasing number of elderly people are likely to need reoperation for valvular diseases in the future. This is particularly important when considering transcatheter options that have yet to become the established standard of care. Regarding the limitations of the recently published studies, information concerning the safety and efficacy of redo valvular surgery, as well as feasibility and further clinical course during follow-ups, remains insufficient.

**Disclosure Statement**

None declared.

**References**