Original Article

Dysfunction of mechanical heart valve prosthesis: experience with surgical management in 48 patients

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Background: Dysfunction of mechanical heart valve prostheses is an unusual but potentially lethal complication after mechanical prosthetic valve replacement. We seek to report our experience with mechanical valve dysfunction regarding etiology, surgical techniques and early outcomes.

Methods: Clinical data of 48 patients with mechanical valve dysfunction surgically treated between October 1996 and June 2011 were analyzed.

Results: Mean age was 43.7±10.9 years and 34 were female (70.8%). The median interval from primary valve implantation to dysfunction was 44.5 months (range, 1 hour to 20 years). There were 21 emergent and 27 elective reoperations. The etiology was thrombosis in 19 cases (39.6%), pannus in 12 (25%), thrombosis and pannus in 11 (22.9%), improper disc orientation in 2 (4.1%), missing leaflet in 1 (2.1%), excessively long knot end in 1 (2.1%), endogenous factor in 1 (2.1%) and unidentified in 1 (2.1%). Surgical procedure was mechanical valve replacement in 37 cases (77.1%), bioprosthetic valve replacement in 7 (14.9%), disc rotation in 2 (4.2%) and excision of excessive knot end in 1 (2.1%). Early deaths occurred in 7 patients (14.6%), due to low cardiac output in 3 (6.3%), multi-organ failure in 2 (4.2%) and refractory ventricular fibrillation in 2 (4.2%). Complications occurred in 10 patients (20.8%).

Conclusions: Surgical management of mechanical valve dysfunction is associated with significant mortality and morbidity. Earlier identification and prompt reoperation are vital to achieving better clinical outcomes. The high incidence of thrombosis in this series highlights the need for adequate anticoagulation and regular follow-up after mechanical valve replacement.

Keywords: Mechanical heart valve prosthesis; dysfunction; surgery; reoperation; outcome

Submitted Sep 15, 2015. Accepted for publication Dec 02, 2015.
doi: 10.3978/j.issn.2072-1439.2015.12.25
View this article at: http://dx.doi.org/10.3978/j.issn.2072-1439.2015.12.25

Although the long-term outcome of mechanical value replacement have improved significantly with the progress of materials, design, manufacturing and surgical techniques, prosthetic valve dysfunction remains a very serious complication after mechanical valve replacement with high mortality and morbidity (1). Numerous studies have been carried out to identify the risk factors for prosthetic valve dysfunction (2-13). An algorithm for management of obstructive thrombosed prosthetic heart valve has been developed recently (4).

Between October 1996 and June 2011, a total of 16,893 cases of mechanical heart valve replacement were performed in our institute. Among these there were 48 (0.28%) cases of reoperations for mechanical heart valve dysfunction. In this retrospective study, we seek to report our experience with surgical management of this group of patients with emphasis on etiology, surgical strategy and early outcomes.

Patients and methods

The Ethics Committee of Fu Wai Hospital and Cardiovascular Institute approved this retrospective study and waived the need for individual patient consent for this study.

Patients

There were 14 males (29.2%) and 34 females (70.8%), with a mean age of 43.7±10.9 years (range, 16–63 years). The median time from the primary valve replacement to onset of symptoms or diagnosis and to reoperation was 44.5 months (range, 1 hour to 20 years) and 51 months (range, 1.1 hours to 23 years), respectively; while the median interval from symptomatic onset or diagnosis to reoperation was 2 months (range, 0.1 hour to 61 months) (*Table 1*).

The primary operation was mitral valve replacement in 23 cases (47.9%, including five with a concomitant tricuspid valve repair), aortic valve replacement in 12 (25.0%, including one Bentall operation), aortic and mitral valve replacement in 11 (22.9%), tricuspid valve replacement and aortic + mitral + tricuspid valve replacement, in one each (2.1%) (*Figure 1*). *Table 2* lists the brands (model) and types of 61 valve prostheses used in the primary operation. Among these, 34 were tilting disc (55.7%) and 27 bileaflet (44.3%); 24 were implanted (39.3%) in the aortic (12 tilting disc, 12 bileaflet), 35 (57.4%) in the mitral (22 tilting disc, 13 bileaflet), and 2 bileaflet prostheses (3.3%) in the tricuspid position (*Table 2*).

The clinical presentation varied considerably from dyspnea and palpitation with changes in valve clicks on auscultation to sudden onset of ventricular fibrillation immediately following the primary valve replacement. Electrocardiogram was abnormal in 37 cases (77.1%), including atrial fibrillation in 23 (47.9%), ventricular hypertrophy in 10 (20.8%) and ventricular premature beat in 4 (8.3%). Chest roentgenograph showed a cardiothoracic ratio >0.55 in 17 patients (35.4%). Echocardiography showed that the free mobility of the prosthetic disc or

Table 1 Preoperative clinical profile

Variable	Value (percentage or range)
Age (year)	43.7±10.9
Female	34 (70.8)
Primary valve replacement	
Valves replaced	61
Mitral	35 (57.4)
Aortic	24 (39.3)
Tricuspid	2 (3.3)
Type of valve prosthesis	
Bileaflet	27 (44.3)
Tilting disc	34 (55.7)
Interval (median)	
Initial valve replacement to presentation	44.5 (1 hour–20 years)
Initial valve replacement to reoperation	51.0 (1.1 hour–23 years)
Symptom onset/diagnosis to reoperation	2.0 (0.1 hour–61 months)
Symptoms	
Dyspnea	14 (29.2)
Lower extremity edema	8 (16.7)
Syncope	7 (14.6)
Dizziness	3 (6.3)
Vomiting	3 (6.3)
Gross hematuria	1 (2.1)
Cardiothoracic ratio >0.55	17 (35.4)
Electrocardiogram	
Atrial fibrillation	23 (47.9)
Ventricular hypertrophy	10 (20.8)
Ventricular premature beat	4 (8.3)
Echocardiograph	
Left atrial diameter (mm)	48.7±11.1 [35–86]
Left ventricular end-diastolic diameter (mm)	54.1±11.5 [38–83]
Left ventricular ejection fraction	0.55±0.11 (0.20–0.70)
New York Heart Association functional class	
Class II	17 (35.4)
Class III	18 (37.5)
Class IV	13 (27.1)

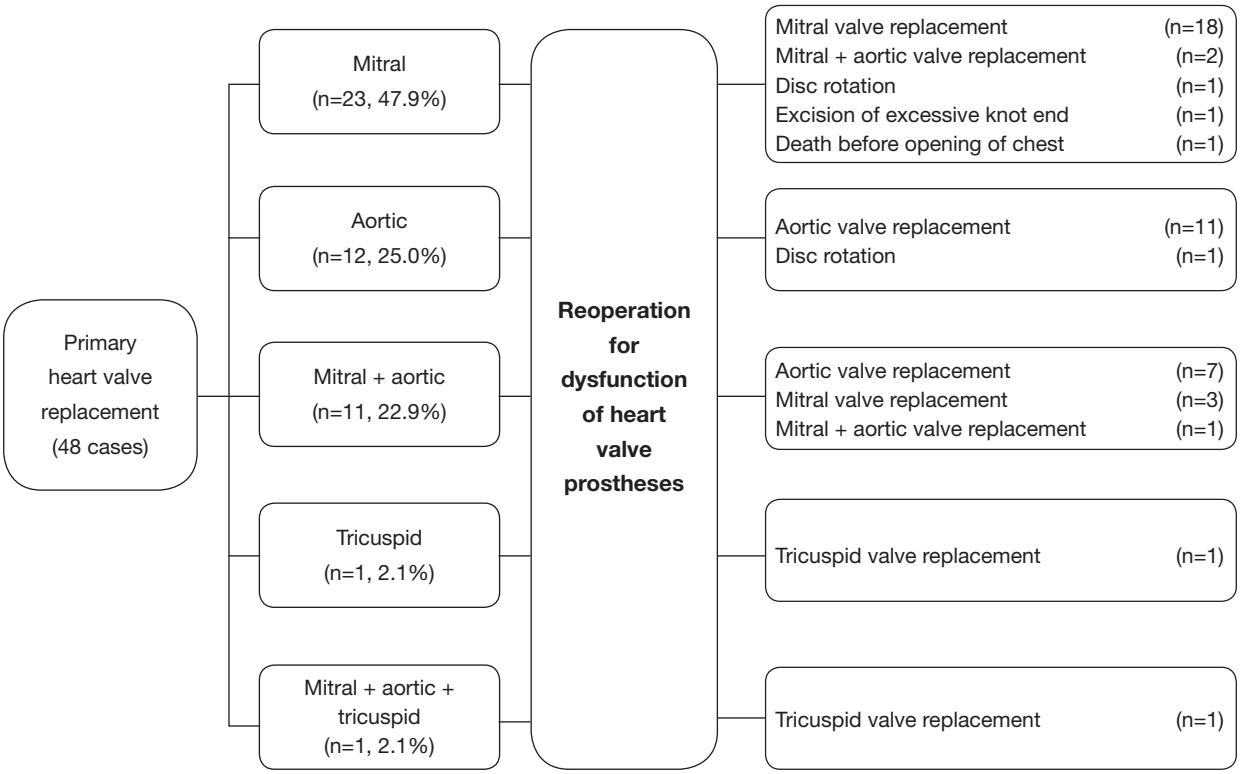

Figure 1 Flow diagram showing procedures at primary valve replacement and reoperations.

leaflet was interfered, which resulted in obstruction or regurgitation of the prosthetic valve. The preoperative New York Heart Association (NYHA) functional class was II in 17 patients (35.4%), III in 18 (37.5%) and IV in 13 (27.1%) (*Table 1*).

Surgical technique

The reoperation was done under moderate hypothermic cardiopulmonary bypass with cold potassium cardioplegia. There were 21 (43.8%) emergency and 27 (65.2%) elective operations. In 46 patients, the operation was performed via a repeat median sternotomy with cannulation of the ascending aorta and vena cava or right atrium. Left thoracotomy and femoral artery cannulation was used in one patient who sustained cardiac arrest after induction of general anesthesia.

Results

The causes for mechanical valve dysfunction were thrombosis in 19 patients (39.6%), pannus formation in 12 (25.0%), pannus formation with thrombosis in 11 (22.9%), improper disc orientation in 2 (4.1%), missing leaflet in 1 (2.1%), excessively long knot end in 1 (2.1%), endogenous factor in 1 (2.1%) and unidentifiable in 1 (2.1%). In one patient who had an aortic valve replacement 10 years ago and suffered from dyspnea for 2 months, one leaflet of the previously implanted bileaflet prosthesis was found to be missing during reoperation.

Reoperations was done in 47 (97.9%) cases, including mitral valve replacement in 21 (43.7%), aortic valve replacement in 18 (37.5%, including one Bentall operation), mitral and aortic valve replacement in 3 (6.3%), tricuspid valve replacement and disc rotation in 2 (4.2%) each, and excision of excessive knot end in 1 (2.1%) (*Figure 1*). There were 37 mechanical and 7 bioprosthetic valve replacements, using 40 (85.1%) mechanical (10 tilting disc and 30 bileaflet; 20 in mitral, 20 in aortic) and 7 (14.9%) bioprosthetic valves (4 in mitral, 2 in tricuspid and 1 in aortic position) (*Table 3*). Concomitant procedures included tricuspid valve repair in 13 (27.1%) patients, repair of aneurysm of the sinus of Valsalva in 1 (2.1%).

The times of cardiopulmonary bypass and aortic

Table 2 Details of prostheses used in the primary valve replacement

Primary valve replacement	Cases	Brand (model)	Type	No. of valves used
Mitral	23	Medtronic Hall	Monoleaflet	8
		AorTech	Monoleaflet	2
		St. Jude	Bileaflet	2
		Carbomedics	Bileaflet	1
		Sorin	Monoleaflet	2
		G-K	Monoleaflet	2
		Not available	Bileaflet	6
Aortic	12	Medtronic Hall	Monoleaflet	4
		St. Jude Regent	Bileaflet	3
		ATS	Bileaflet	1
		Jyros	Bileaflet	1
		Not available	Monoleaflet	2
		Not available	Bileaflet	1
Mitral + aortic	11	Medtronic Hall	Monoleaflet	10
		Sorin	Monoleaflet	4
		St. Jude Regent	Bileaflet	3
		Medtronic	Bileaflet	2
		Jyros	Bileaflet	1
		Not available	Bileaflet	2
Tricuspid	1	Not available	Bileaflet	1
Mitral + aortic + tricuspid	1	Edwards	Bileaflet	3

cross-clamp were 149±59 (range, 51–391 minutes) and 90±33 minutes (range, 0–142 minutes), respectively. The median time to extubation was 16 hours (range, 5–144 hours).

Seven patients expired (14.6%, 7/48), six of whom (85.7%) died after an emergency reoperation. The mortality rate was significantly higher in emergency (28.6%, 6/21) than in elective patients (3.7%, 1/27; P=0.03). The cause of death was low cardiac output in three cases (6.3%), multi-organ failure in two (4.2%) and intractable ventricular fibrillation in two (4.2%). One female patient expired intraoperatively due to refractory ventricular fibrillation before opening of the chest and the etiology was not identified. Extracorporeal membrane oxygenation was used in one patient who could not wean from cardiopulmonary bypass but failed to save his life.

Morbidity occurred in 10 patients (20.8%), including reexploration for bleeding in two (4.2%), wound infection in two (4.2%) and pneumonia in two (4.2%), endocarditis in one (2.1%), renal failure in one (2.1%), hepatic failure in one (2.1%) and refractory hiccup in one (2.1%) (*Table 3*). All patients with complications were cured and discharged uneventfully.

Discussion

Prosthetic valve dysfunction is one of the most serious complications after mechanical valve replacement and the optimal management remains controversial. In literature, the incidence was 0.1–6.0% per patient year (1,5-10) and the mean interval between the initial valve replacement and reoperation was 10–16 years (9,12,14,15). In this series, mechanical valve prosthetic dysfunction accounted for 0.28% of the mechanical valve replacements in our institution and the median duration from the initial valve implantation to reoperation was 51 months.

The clinical presentation varied from no symptoms to acute heart failure even sudden cardiac arrest. On

Table 3 Operative data and early outcomes

Variable	Value (percentage or range)
Emergency/elective reoperation	21/27
Etiology	
Thrombosis	19 (39.6)
Pannus formation	12 (25.0)
Thrombosis + pannus formation	11 (22.9)
Improper disc orientation	2 (4.1)
Missing leaflet	1 (2.1)
Excessively long knot end	1 (2.1)
Endogenous factor	1 (2.1)
Unidentified	1 (2.1)
Procedure at reoperation	47
Mitral valve replacement	21 (44.7)
Aortic valve replacement	18 (38.3)
Aortic + mitral valve replacement	3 (6.4)
Tricuspid valve replacement	2 (4.3)
Disc rotation	2 (4.3)
Excision of excessive knot end	1 (2.1)
Prostheses used in reoperation	47
Bileaflet	30 (63.8)
Tilting disc	10 (21.3)
Bioprosthetic	7 (14.9)
Cardiopulmonary bypass time (minutes)	149±59
Cross-clamp time (minutes)	90±33
Time to extubation (median, hours)	16 [5–144]
Mortality	7 (14.6)
Morbidity	10 (20.8)
Reexploration for bleeding	2 (4.2)
Pneumonia	2 (4.2)
Wound infection	2 (4.2)
Endocarditis	1 (2.1)
Renal failure	1 (2.1)
Hepatic failure	1 (2.1)
Refractory hiccup	1 (2.1)

auscultation, valve clicks may be diminished or absent with additional systolic or diastolic murmurs. Detection of the "double click" may be useful for early diagnosis of dysfunction of bileaflet prostheses. Although transthoracic echocardiography (TTE) is the most commonly utilized imaging modality (4), it is less sensitive in detecting the reduced prosthetic disc/leaflet motion than cinefluoroscopy. Transesophageal echocardiography (TEE) (14,16) especially 3-dimensional TEE (17) may be the best diagnostic tool, which can define the causes better and helps in guiding therapy, risk stratification and monitoring follow-up outcomes (18). In cases when it is difficult to differentiate pannus from thrombosis (14,19), Doppler study can help in the diagnosis by measuring hemodynamic parameters (8). Besides, multidetector-row computed tomography can identify causes of prosthetic valve dysfunction that constitute surgical indications but are missed at echocardiography or fluoroscopy (20). In this series, the diagnosis was confirmed by Doppler echocardiography in all patients.

Mechanical valve dysfunction can be classified as endogenous and exogenous according to the etiology. Endogenous dysfunctions are caused by valve damage or defect, which has become extremely rare with the improvement of design, materials, manufacture and detection methods *in vitro* (21). Exogenous causes include inappropriate selection of prosthesis, technical issues or other complications, such as thrombosis, excessive pannus overgrowth into the prosthetic rim, excessively long knot end, residual chordae tendineae stuck in the prosthetic sewing ring, extremely long residual papillary muscles in left ventricle or calcified tissues under the prosthesis hampering leaflet mobility. The most common causes of mechanical valve dysfunction are thrombosis and pannus formation, which was present in 87.5% of patients in this series.

Thrombosis is usually due to inadequate anticoagulation (22) and associated with atrial fibrillation (9) and low cardiac function. However, Maribas *et al.* reported that valve thrombosis occurs with similar frequency in patients with bioprosthetic valves and in those with mechanical valves who are receiving adequate anticoagulant therapy (23). In this series, thrombosis was seen in 62.5% (30/48) of patients; among them 16 (33.3%) developed atrial fibrillation and 21 (43.7%) were in NYHA functional class III or IV preoperatively. This high incidence of thrombosis highlights the need for adequate anticoagulation and regular follow-up after initial prosthetic valve replacement. Owing to the low pressure of the right heart, the incidence of tricuspid valve dysfunction (almost all caused by thrombosis) is as high as 20% (11). In this series, there were two cases (4.2%) of tricuspid valve dysfunction caused by thrombosis; at reoperation tissue valves were chosen to reduce the risk of recurrent thrombosis.

Pannus formation was found in 47.9% of patients in this series, including 11 (22.9%) with concomitant thrombosis.

A study of 87 cases with mitral valve obstruction has found that pannus formation is more frequent than thrombus formation, but thrombosis is of earlier onset than pannus formation (13). Pannus is an overgrowth of fibrous tissue invading the valve orifice and may result from an non-immune inflammatory reaction (13), which is evidenced by elevated levels of plasma transforming growth factor beta 1 (24), protein C and protein S (25). Histologically the pannus tissue incorporates collagen and elastic tissues containing endothelial cells, chronic inflammatory cells and proliferation of myofibroblasts (26). Several studies reported that pannus formation causing prosthetic aortic valve stenosis occurred mainly in female patients with a small body surface area (12,14,24,27). This is corroborated by the 70.8% of female patients in our series. Pannus formation has been identified as the second cause of reoperation for mechanical valve (9). Although mitral valve replacement with partial or complete chordal sparing offers the advantage of preserving left ventricular geometry and function, the unresected mitral valve leaflets may exacerbate the host tissue response to the prosthesis and increase the risk of thrombus and/or pannus formation (28). In our practice, we routinely excise the mitral valve about 2.5 mm from the annulus and trim the residual edge neatly.

For patients with mechanical valve dysfunction, surgical decision-making should be based on the cause of valve dysfunction. For endogenous causes, the only effective option is a redo valve replacement. One patient in this series developed acute valve dysfunction after aortic valve replacement, and TEE showed moderate regurgitation. Immediate inspection ruled out thrombosis, excessive knot end or residual papillary muscles and other exogenous factors. Cardiac activity was not restored after the valve orientation was adjusted twice. Decision was made to use another mechanical valve, which restored cardiac activity and achieved stable hemodynamics. This case suggested that the dysfunction might result from endogenous factors, such as intrinsic defect of the valve. Exogenous factors, such as excessively long knot end or residual chordae tendineae, should be avoided in the initial procedure. To prevent small chordae tendineae from interfering with the free mobility of the prosthetic disc or leaflet, normal saline can be injected to fill the ventricular cavity repeatedly to float the slender chordae and to guarantee complete resection. After the knots are tied, the mobility of discs and length of knot ends should be checked routinely. In three patients of this series with improper disc orientation and excessive knot end, prosthetic valve dysfunction was successfully treated with disc rotation and excision of the excessive knot end. Our experience shows that redo valve replacement may not be necessary in cases with certain exogenous causes, such as improper disc orientation or excessive knot end.

For patients with thrombosis, controversy exists regarding the optimal management. Some believe it is enough to debride the thrombosis instead of prosthetic valve replacement owing to the relatively short surgical duration (5,29), and debridement may have lower risk and mortality than valve replacement. Albeit there are reports that valve function could be normal after debridement, it should be noted that the thrombus usually adheres firmly to the prosthetic valve disc, which makes complete removal difficult (3,9). Any slight damage of the disc surface is likely to cause the recurrence of thrombosis. Although the rate of recurrent thrombosis following clot removal and debridement has been shown to be higher than after valve replacement, the difference in recurrent thrombosis between redo valve replacement and clot debridement was not statistically significant (7,30). Therefore, thrombus removal might be considered in patients with high surgical risks. Deviri and associates argue that the decision to replace or debride the valve should be left to the surgeon, based on anatomic and technical factors at the time of surgery (2). In addition, pannus formation is the result of an exuberant healing process in response to a foreign body and takes longer time to become clinically manifest, often in combination with thrombosis. Because the fibrotic overgrowth generally occurs on both the prosthetic and natural valve surfaces, prosthetic valve replacement is preferred to debridement in patients with pannus (13). Nevertheless, some believe that redo valve replacement might be advisable only in patients with extensive, circumferential pannus (12,27). On the other hand, more recent studies have shown that thrombolysis can restore adequate function of the thrombosed prosthetic valve with high success rate and lower mortality and morbidity rates (22,31,32). In literature, thrombolysis has achieved a success rate of 64–89%; the incidence rate was 5–19% for systemic embolism and 5–8% for major bleeding. But the incidence rate of recurrence was as high as 15–31% with a mortality of 6–12.5% (4,33-37). Based on this, thrombolysis is recommended as the first-line treatment for all patients with left-sided prosthetic valve thrombosis in the Society for Heart Valve Disease guidelines and for patients with low thrombus burden (<0.8 cm^2) regardless of NYHA functional class in the

American College of Chest Physicians guidelines (35). It is believed that thrombolysis has a higher chance of success if the thrombus is younger than 14 days (22,33).

No matter what treatment would be taken, the mortality rate of prosthetic dysfunction was significantly higher than the primary valvular disease. It was reported that the overall operative mortality was 10.8–15% and 20–40% in emergency operations (2,5,23,38) and as high as 62.5% in early series (39). In this series the overall mortality was 15.2% and 6 of 7 (85.7%) deaths occurred after emergency reoperation. The high mortality of 28.6% in emergency patients may be due to the poor general conditions, worsened cardiac function and lack of sufficient preoperative preparation. While emergency reoperation may be the only life-saving therapy for emergency cases, prompt and sufficient preoperative preparations should be made for patients with chronic prosthetic dysfunction to improve their general conditions and cardiac function, so as to achieve better surgical outcomes.

Limitations

The retrospective study has several limitations, such as the relatively small number of patients and the lack of late follow-up after the reoperation. Specifically, information was not available about the surgical techniques and valve prostheses used in initial valve replacement. Details of anticoagulation management after the initial procedure were also missing, such as the target international normalized ratio (INR), frequency of INR measurements and especially the INR values prior to the occurrence of valve dysfunction.

Conclusions

The results of this study show that thrombus and pannus are two major causes for dysfunction of mechanical valve prosthesis and surgical management is associated with significant mortality and morbidity. Earlier identification and prompt reoperation are vital to achieving better clinical outcomes. The high incidence of thrombosis in this series highlights the need for adequate anticoagulation and regular follow-up after initial mechanical valve replacement. Further study is warranted to determine the long-term outcome of reoperation in patients with mechanical valve dysfunction.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Cite this article as: Ma WG, Hou B, Abdurusul A, Gong DX, Tang Y, Chang Q, Xu JP, Sun HS. Dysfunction of mechanical heart valve prosthesis: experience with surgical management in 48 patients. J Thorac Dis 2015;7(12):2321-2329. doi: 10.3978/j.issn.2072-1439.2015.12.25

