European Review for Medical and Pharmacological Sciences 2017; 21: 3436-3440

Concomitant mitral valve replacement and tricuspid valvuloplasty for severe mitral stenosis

X.-D. HOU, F. DING, X.-K. WANG, X.-G. LIU, K. YI, P. ZHANG, T. YOU

Department of Cardiac Surgery, Gansu Province People's Hospital, Lanzhou, Gansu Province, China

Abstract. – OBJECTIVE: The purpose of this work is to analyze the clinical results of treating severe mitral stenosis (MS) with mild to moderate functional tricuspid regurgitation (FTR) with mitral valve replacement (MVR) alone or together with two different methods of tricuspid valvuloplasty (TVP).

PATIENTS AND METHODS: We split 132 patients into three groups: simple MVR with 47 cases (control group), MVR+ TVP (De Vega loop reduction) with 45 cases (observation group 1) and MVR+ TVP (Edwards MC3 tricuspid forming ring implantation) with 40 cases (observation group 2).

RESULTS: As expected, surgery for both observation groups was longer than for the control group, but we found no differences in aortic clamping time, cardiopulmonary bypass time, perioperative complications, and postoperative hospital stay. We found significantly fewer complications in both observation groups compared to the control group. After surgery, the diameter of the tricuspid valve ring and the maximum reflux bundle were significantly lower in the observation groups compared to the control group.

CONCLUSIONS: Overall, the long-term clinical effect of combined MVR and TVP to treat severe MS with mild to moderate FTR is better than using the simple MVR procedure. Our results also suggest that the Edwards MC3 tricuspid forming ring implantation is superior to the De Vega loop reduction.

Key Words

Mitral valve replacement, Tricuspid valvuloplasty, Functional tricuspid regurgitation, De Vega loop reduction, Edwards MC3 tricuspid forming ring implantation.

Introduction

Rheumatic heart disease is mainly caused by valvular damage[1]. Mitral stenosis (MS) combined with functional tricuspid regurgitation (FTR) accounts for 50-65% of all cases[2]. Mitral valve replacement (MVR) significantly improves left ventricular function and prognosis[3]. The observed residual tricuspid regurgitation is an independent risk factor that affects postoperative long-term survival, and the mortality rate of the second surgery is up to 35-40%[4]. FTR is mainly caused by tricuspid annulus expansion or poor combined flap of the valve without clear organic lesion[5]. The current view is that severe FTR requires tricuspid valvuloplasty (TVP) together with MVR, whereas for light and moderate FTR, the benefits of the combined surgery are not clear[6]. Accurate assessment of the degree of FTR is an important factor influencing the surgical strategy and clinical outcome. Echocardiography is most commonly used to measure maximal regurgitant flow area, but surgeons are more likely to explore laparotomy tricuspid valve annulus and "draw water test" results[7,8]. The classic TVP is the De Vega loop reduction characterized by simple surgery and clear benefits. However, the De Vega and Kay method may be risk factors for the recurrence and exacerbation of tricuspid regurgitation after surgery[9]. The Edwards MC3 tricuspid forming ring implantation is closer to the anatomical and physiological function, and is easily standardized[10,11]. The purpose of this study was to analyze the different surgical treatment of severe MS combined with mild to moderate FTR and the long-term clinical effects of MVR and TVP surgeries.

Patients and Methods

Patients

We selected 132 cases with the diagnosis of rheumatic heart disease and severe MS with mild to moderate FTR in our hospital from January 2012 to January 2015. Inclusion criteria: (1) first treatment; (2) tolerance to surgery and anesthesia risk; (3) accept the conditions of the study and complete the clinical studies. Exclusion

Corresponding Author: Tao You, MD, e-mail: houxd2013@126.com

Table I. Baseline data among the three groups.

Group	Control (n=47)	Observation 1 (n=45)	Observation 2 (n=40)	F/χ^2	*p*
Male/female	26/21	25/20	22/18	0.003	0.999
Age (y)	52.3±12.4	51.6±13.5	52.7±14.2	0.162	0.868
Mitral valve flap [cases (%)]	20 (42.6)	19 (42.2)	17 (42.5)	0.001	0.999
Mitral mechanical valve [cases (%)]	27 (57.4)	26 (57.8)	23 (57.5)		
Atrial fibrillation [cases (%)]	12 (25.5)	10 (22.2)	8 (20.0)	0.386	0.824
Right atrial diameter (mm)	38.2±4.5	38.5±4.6	38.4±4.7	0.065	0.893
Right ventricular end diastolic diameter (mm)	36.5±5.2	36.4±5.4	36.7±5.5	0.072	0.825
Pulmonary artery pressure (mmHg)	44.5±7.6	45.2±7.8	45.6±8.2	0.162	0.758
Ventricular septal thickness (mm)	8.56±0.82	8.64±0.93	8.62±0.78	0.112	0.788
NYHA classification	2.6±0.8	2.5±0.7	2.7±0.6	0.198	0.721
Left ventricular ejection fraction (%)	52.3±6.5	51.4±6.7	52.2±6.6	0.213	0.659
Tricuspid valve maximum return flow bundle area (cm^2)	6.2±1.7	6.5±1.8	6.3±1.6	0.265	0.632
Tricuspid valve ring diameter (mm)	42.1±3.6	43.5±3.7	43.7±3.9	0.321	0.598

criteria: (1) combined with other cardiac diseases, such as coronary heart disease, severe hypertension, Marfan's syndrome, congenital heart disease, primary cardiomyopathy, etc.; (2) abnormal coagulation mechanism with recent surgery or bleeding history; (3) rheumatic tricuspid valve disease; (4) failure to follow-up. The 132 subjects were divided into three groups according to the treatment: simple MVR with 47 cases (control group), MVR+ TVP (De Vega loop reduction) with 45 cases (observation group 1) and MVR+ TVP (Edwards MC3 tricuspid forming ring implantation) with 40 cases (observation group 2). Baseline data in the three groups were comparable (Table I). This study was approved by the Ethics Committee of Nanyang Central Hospital. Signed written informed consents were obtained from all participants.

Methods

The same surgery and nursing team completed all the studies according to standard medical procedures. Optimized drug therapy (diuretics, digoxin, nitroglycerin, etc.) reduces pulmonary artery pressure. Patients received general anesthesia, median incision, low temperature (27-29°C) cardiopulmonary bypass, aortic root cold HTK myocardial preservation solution perfusion, MVR after the heart beat smoothly (biological or mechanical valve), take TVP after rewarming and re-beat. During surgery, the "water experiment" was repeated to judge tricuspid valvular regurgitation and tricuspid valve test was used for quantitative assessment of tricuspid annuloplasty ring size. The main steps of the De Vega loop reduction were the ring contraction for the 3-0 Prolene line double-headed needle with gasket 2, from the front of the junction, along the tricuspid annulus, which take the continuous suture to the posterior septum. The needle interval was 3-5 mm, two stitches interval was 2-3 mm. The needle exited, on the gasket tighten suture and knot, which made the valve fit 2-2.5 finger. The "water experiment" confirmed the good combination. The main step of the Edwards MC3 tricuspid forming ring implantation is the selection of an appropriate forming ring from the proximal end of the valve flap closure of about 1 needle (exten-

Table II. Surgical indexes.

Group	Operation time (min)	Aortic clamping time (min)	Cardiopulmonary bypass time (min)	Postoperative hospital stay (d)
Control	135.8 ± 16.9	62.3 ± 8.2	114.5 ± 10.2	12.5 ± 3.6
Observation 1	157.9 ± 21.3	64.5 ± 8.3	108.6 ± 12.4	13.4 ± 3.5
Observation 2	164.2 ± 22.5	65.1 ± 8.7	123.7 ± 13.3	12.8 ± 3.3
F	4.562	0.324	0.462	0.285
p	0.031	0.639	0.528	0.768

ded to the front and back flap of tricuspid), to the end of the septum. The method of equal division was used to take 9 needles. The strengthen of the postoperative drug therapy (dopamine, milrinone etc.) was continued, and vital signs were monitored.

Observation index

The follow-up time was 8-45 months with a median time of 32.0 months. The operation time, aortic clamping time, cardiopulmonary bypass time and postoperative hospital stay, the occurrence of perioperative, and postoperative complications, were analyzed. The diameter of the tricuspid ring, maximum return flow tract area, right ventricular end diameter, right atrial diameter, pulmonary artery pressure, ventricular septal thickness, NYHA classification, and left ventricular ejection fraction were followed up after surgery.

Statistical Analysis

We used SPSS20.0 software (Inc. Chicago, IL, USA) for statistics analysis. Measurement data was expressed by mean ± standard deviation, comparisons between groups were performed by single factor ANOVA analysis, pairwise comparison was tested by LSD-t, comparison within group was tested by paired t, count data was expressed by cases or (%), comparisons between groups were tested by χ^2; $p<0.05$ indicated that the difference was statistically significant.

Results

Surgery indexes

Due to the additional procedures for the two observation groups, the surgery time for both observation groups was more than 20 min longer than for the control group (Table II). Other parameters we measured during the surgery, including aortic clamping time, cardiopulmonary bypass time, and postoperative hospital stay, were similar in the three groups (Table II).

Perioperative complications

In the control group, we had one case of pulmonary infection, one of hepatic and renal dysfunction, and one of acute heart failure, with a total occurrence of 6.38% (3/47). In the observation group 1, we had one case of liver and renal dysfunction, one of acute heart failure, and one of acute heart failure, with a total occurrence rate of 6.67% (3/45). In the observation group 2, we had one case of liver and kidney dysfunction and one of acute heart failure, with a total occurrence rate of 5% (2/40). With these few perioperative complications, we found no significant differences between the three groups ($p>0.05$).

Follow-up complications

Table III summarizes the post-operative complications. In the control group, we had one case of pulmonary infection, two of hepatic and renal dysfunction, five of acute heart failure, three underwent a second surgery, and one death, with a total occurrence rate was 25.5% (12/47). In observation group 1, we had one case of pulmonary infection, two of liver and renal dysfunction, two of acute heart failure, with a total occurrence rate of 11.1% (5/45). In the observation group 2, we had one case of pulmonary infection, one case of liver and kidney dysfunction, and one case of acute heart failure, with a total occurrence rate of 7.5% (3/40). The differences between the control and the observations groups were statistically significant (Table III).

Tricuspid regurgitation and ventricular function

To determine the effectiveness of the three surgical options, we measured several cardiac functional indexes immediately after surgery and one month later (Table IV). Following surgery,

Table III. Comparison of follow-up complications [cases (%)].

Group	# cases	Pulmonary infection	Liver/ kidney dysfunction	Acute/ chronic heart failure	Reoperation	Death	Total incidence rate
Control	47	1	2	5	3	1	12 (25.53)
observation 1	45	1	2	2	0	0	5 (11.11)
observation 2	40	1	1	1	0	0	3 (7.50)
χ^2							6.332
p							0.042

Table IV. Tricuspid regurgitation and left and right ventricular function indexes.

Group		Control	Observation 1	Observation 2	F	p
Tricuspid valve ring diameter (mm)	Postoperative	44.6±3.8	33.5±2.2	32.7±2.4	5.231	0.019
	1 month follow-up	48.2±4.3	36.5±2.4	32.8±2.3	5.847	0.006
Maximum reflux bundle area (cm^2)	Postoperative	8.3±1.8	4.2±0.6	4.0±0.5	5.328	0.016
	1 month follow-up	10.5±2.2	4.6±0.8	4.2±0.6	5.964	0.004
Right ventricular end diastolic diameter (mm)	Postoperative	36.6±5.5	36.4±5.6	36.5±5.2	0.235	0.766
	1 month follow-up	38.2±5.8	36.8±5.4	36.3±5.3	3.524	0.036
Right atrial diameter (mm)	Postoperative	38.3±4.6	38.2±4.4	38.3±4.5	0.121	0.869
	1 month follow-up	39.2±4.8	38.4±4.5	38.1±4.3	3.326	0.034
Pulmonary artery pressure (mmHg)	Postoperative	45.2±8.2	45.1±7.6	45.2±7.7	0.069	0.914
	1 month follow-up	47.6±8.3	45.3±7.9	45.3±7.8	3.421	0.038
Interventricular septal thickness (mm)	Postoperative	8.62±0.76	8.65±0.83	8.64±0.84	0.163	0.854
	1 month follow-up	8.53±0.92	8.64±0.85	8.65±0.82	3.052	0.039
NYHA classification	Postoperative	2.2±0.7	2.3±0.6	2.2±0.8	0.142	0.859
	1 month follow-up	2.9±0.9	2.5±0.5	2.3±0.7	4.235	0.028
Left ventricular ejection fraction (%)	Postoperative	53.6±7.3	53.5±6.9	53.4±6.6	0.163	0.847
	1 month follow-up	48.7±8.1	50.9±7.3	52.6±7.4	4.963	0.025

we found no differences in the right ventricular end diastolic diameter, right atrial diameter, pulmonary artery pressure, ventricular septal thickness, NYHA score, and left ventricular ejection fraction between the three groups. However, the diameter of tricuspid valve ring and the maximum reflux bundle were significantly lower in both observation groups compared to the control group. At one-month follow-up, we found significant differences between both observations groups and the control group in all the parameters analyzed, supporting the benefits of the combined MVR and TVP surgeries (Table IV). However, the values between the two observation groups were very similar.

Discussion

Fukuda et al[12] observed that valve leaf pulling distance (the distance between the closed point of the tricuspid petal and the plane of the valve annulus) and traction area (the triangle area of the closed point of the valve and the width of the valve ring) were independent risk factors for FTR. When ring diameter was >21 mm/m2 or ≥35 mm combined with the pacing lead of the tricuspid valve and atrial fibrillation, it is recommended to undertake TVP without considering the degree of reflux[12]. In 2012, the valvular disease guidelines of European Society of Cardiology (ESC) recommended TVP (IIa) in cases of mild or moderate FTR, ring diameter ≥10 mm or >21 mm/m^2 [13]. The typical TAD only occurs in the anterior and posterior rings, and the length of the septum is essentially unchanged. The De Vega annuloplasty only sews at the junction to the back across the border, and septal tricuspid valve annulus is relatively fixed. In the continued expansion of pulmonary hypertension and right ventricular, septal anterior and posterior septal annulus junction will still gradually expand, eventually leading to recurrence of reflux[14]. Also, poor long-term effects are related to suture rupture, suture floating on the outside of the organization, line loose, suture lobe in the lobe avulsion or shrinkage, and valve deformation[15]. The tricuspid valve is "saddle shaped" and the expansion of the aortic root is relatively shallow but deep in the septum. Edwards MC3 valve ring has a three-dimensional design, and it can be better adapted to the shape of the tricuspid valve. Also, the long-term repair effect is better[16]. The titanium alloy treatment can maintain certain elasticity, reduce the tension of the suture and the recurrence rate of reflux[17]. Our work demonstrates the safety of combining MVR

and TVP in the same surgery, with the only caveat of the extra time needed to complete the TVP. This study took TVP in the case of heart rewarming and re-beating, which might be the important reason for the decrease of complications in the perioperative period. Both observation groups had significantly fewer complications than the control group. The patients with acute and chronic heart failure and the need of the secondary surgery for recurrent reflux decreased, which supported the long-term effect of TVP. Following surgery, the diameter of the tricuspid valve ring and the maximum reflux bundle of the observation groups were significantly lower compared to the control group, indicating the immediate benefits of the combined surgery. One month after surgery, right ventricular end diastolic diameter, right atrial diameter, pulmonary artery pressure, ventricular septal thickness, NYHA classification, and left ventricular ejection fraction, were significantly improved in the observation groups.

Conclusions

The long-term clinical benefits of MVR combined with TVP in the treatment of severe MS with mild to moderate FTR are superior to only MVR. Additionally, the Edwards MC3 tricuspid forming ring implantation may be superior to the De Vega loop reduction, but these conclusions need further validation with larger samples and independent studies.

Conflict of Interest:

The Authors declare that they have no conflict of interests.

References

1) De Rosa G, Pardeo M, Stabile A, Rigante D. Rheumatic heart disease in children: from clinical assessment to therapeutical management. Eur Rev Med Pharmacol Sci 2006; 10: 107-110.
2) Boyaci A, Gokce V, Topaloglu S, Korkmaz S, Goksel S. Outcome of significant functional tricuspid regurgitation late after mitral valve replacement for predominant rheumatic mitral stenosis. Angiology 2007; 58: 336-342.
3) Han D, Zhang Y, Xue DM, Wang WL, Yan WJ. Valve replacement for valvular heart disease with giant left ventricle. Eur Rev Med Pharmacol Sci 2015; 19: 3001-3005.
4) Cao H, Chen Q, Li QZ, Chen LW, Zhang GC, Chen DZ, Qiu ZH, Hu YN, He JJ. A clinical study of thoracoscopy-assisted mitral valve replacement concomitant with tricuspid valvuloplasty, with domestically manufactured pipeline products for cardiopulmonary bypass. J Cardiothorac Surg 2014; 9: 160.
5) Song JM, Kang DH, Song JK, Jeong YH, Lee CW, Hong MK, Kim JJ, Park SW, Park SJ. Outcome of significant functional tricuspid regurgitation after percutaneous mitral valvuloplasty. Am Heart J 2003; 145: 371-376.
6) Angeloni E, Melina G, Benedetto U, Roscitano A, Refice S, Quarto C, Comito C, Pibarot P, Sinatra R. Impact of prosthesis-patient mismatch on tricuspid valve regurgitation and pulmonary hypertension following mitral valve replacement. Int J Cardiol 2013; 168: 4150-4154.
7) Dreyfus GD, Corbi PJ, Chan KM, Bahrami T. Secondary tricuspid regurgitation or dilatation: which should be the criteria for surgical repair? Ann Thorac Surg 2005; 79: 127-132.
8) Li J, Wang F, Zhang N, He Q, Sun YJ, Wang HY, Yin DM. The assessment of the cardiac compensatory function of elderly people with coronary artery disease by quantitive dobutamine stress echocardiography. Eur Rev Med Pharmacol Sci 2016; 20: 3648-3652.
9) Raja SG, Dreyfus GD. Surgery for functional tricuspid regurgitation. Current techniques, outcomes and emerging concepts. Expert Rev Cardiovasc Ther 2009; 7: 73-84.
10) Filsoufi F, Salzberg SP, Coutu M, Adams DH. A three-dimensional ring annuloplasty for the treatment of tricuspid regurgitation. Ann Thorac Surg 2006; 81: 2273-2277.
11) De Bonis M, Lapenna E, Taramasso M, Manca M, Calabrese MC, Buzzatti N, Rossodivita A, Pappalardo F, Dorigo E, Alfieri O. Mid-term results of tricuspid annuloplasty with a three-dimensional remodelling ring. J Card Surg 2012; 27: 288-294.
12) Fukuda S, Gillinov AM, McCarthy PM, Matsumura Y, Thomas JD, Shiota T. Echocardiographic follow-up of tricuspid annuloplasty with a new three-dimensional ring in patients with functional tricuspid regurgitation. J Am Soc Echocardiogr 2007; 20: 1236-1242.
13) Rogers JH, Bolling SF. Approaches to the management of functional tricuspid regurgitation. J Comp Eff Res 2015; 4: 665-676.
14) Tang GH, David TE, Singh SK, Maganti MD, Armstrong S, Borger MA. Tricuspid valve repair with an annuloplasty ring results in improved long-term outcomes. Circulation 2006; 114: I577-I581.
15) Garatti A, Nano G, Bruschi G, Canziani A, Colombo T, Frigiola A, Martinelli L, Menicanti L. Twenty-five year outcomes of tricuspid valve replacement comparing mechanical and biologic prostheses. Ann Thorac Surg 2012; 93: 1146-1153.
16) Hata H, Fujita T, Shimahara Y, Sato S, Kobayashi J. Early and mid-term outcomes of aggressive tricuspid annuloplasty with the MC3 ring. J Heart Valve Dis 2014; 23: 601-608.
17) Kawaura H, Aoki A, Omoto T, Maruta K, Iizuka H. Effect of the septal adjustment technique for tricuspid annuloplasty with an MC3 ring. Gen Thorac Cardiovasc Surg 2015; 63: 273-278.