A novel technique for correction of severe tricuspid valve regurgitation due to complex lesions

Michele De Bonis*, Elisabetta Lapenna, Giovanni La Canna, Antonio Grimaldi, Francesco Maisano, Lucia Torracca, Alessandro Caldarola, Ottavio Alfieri

Department of Cardiac Surgery, San Raffaele University Hospital, Via Olgettina 60, 20132 Milan, Italy

Received 28 September 2003; received in revised form 24 January 2004; accepted 28 January 2004

Abstract

Objectives: Correction of tricuspid regurgitation due to complex lesions (not treatable with annuloplasty only) is associated with suboptimal results. To improve the efficacy of valve repair in this context, we developed a new surgical approach, which consists of stitching together the central part of the free edges of the leaflets producing a ‘clover’ shaped valve. Our preliminary experience with this novel technique is reported. Methods: Between 2001 and 2003, 14 patients (mean age 57 ± 17 years), with severe tricuspid regurgitation due to complex lesions, underwent valve repair with this novel approach in combination with annuloplasty. The aetiology of the disease was post-traumatic in five cases, degenerative in eight and secondary to dilated cardiomyopathy in one. Anterior leaflet prolapse/flail was present in most patients associated with posterior and/or septal leaflet prolapse or tethering. Annular and right ventricular dilatation was present in all cases. Mitral valve repair/replacement was concomitantly performed in nine patients. Results: Hospital mortality was 7.1% (1/14). At follow-up extending to 22 months (mean 12 ± 6.3), all survivors were asymptomatic. At the last echocardiogram tricuspid regurgitation was absent or mild in 13 patients and moderate in one. Mean tricuspid valve area and gradient were 4.2 ± 0.4 cm² and 2.7 ± 1.4 mmHg, respectively. Conclusions: Despite the short follow-up, this novel technique appears to be an easy, rapid and effective approach to correct severe tricuspid regurgitation due to complex lesions. Such a repair restored tricuspid valve competence, even in the presence of huge RV dilatation and pulmonary hypertension.

© 2004 Elsevier B.V. All rights reserved.

Keywords: Tricuspid regurgitation; Tricuspid prolapse; Valve repair

1. Introduction

Functional tricuspid regurgitation due to annular dilatation secondary to mitral valve disease represents the most common type of tricuspid valve pathology and is usually effectively corrected by annuloplasty alone. On the other hand, when tricuspid insufficiency is caused by complex lesions like prolapse or flail of multiple cusps, valve repair is more difficult and surgically demanding techniques are usually required in addition to the annuloplasty procedure. For instance, correction of post-traumatic tricuspid regurgitation has been associated with suboptimal results and valve replacement has, therefore, been carried out in the majority of these patients. Similarly, leaflets’ prolapse in severe myxomatous degeneration of the tricuspid valve, despite being a rather uncommon condition, represents a challenging surgical problem requiring a number of different manoeuvres directed towards the leaflets and the entire subvalvular apparatus.

To improve the feasibility and efficacy of valve repair in this context, we developed a new surgical approach, which consists of stitching together the central part of the free edges of the leaflets producing a ‘clover’ shaped valve. Our preliminary experience with this technique for the treatment of post-traumatic tricuspid regurgitation has been recently reported [1]. Since then we have expanded the indications of this novel approach to other different types of tricuspid insufficiency due to complex mechanisms. The description of our overall experience represents the purpose of this paper.
2. Materials and methods

2.1. Patients

Between July 2001 and July 2003, 14 patients with severe tricuspid regurgitation due to complex lesions underwent valve repair with the clover technique in combination with ring annuloplasty. The aetiology of the disease was post-traumatic in five cases, degenerative in eight and secondary to dilated cardiomyopathy in one. The diagnosis was made in all cases by transthoracic followed by trans-oesophageal Doppler echocardiography. A 0–4 + scale was used to define the tricuspid insufficiency degree as follows: no TR (grade 0), mild TR (1 +), moderate TR (2 +), moderate to severe TR (3 +) and severe TR (4 +). The pre-operative clinical characteristics of the patients are detailed in Table 1.

All patients with post-traumatic tricuspid insufficiency had a history of blunt chest trauma secondary to motor vehicle accident 5–25 years before. Mean age was 42 ± 19.2 years and all were in sinus rhythm. Pre-operative echocardiogram revealed the presence of complete or partial flail of the anterior leaflet of the tricuspid valve as a result of chordal rupture (3 patients) or rupture of the anterior papillary muscle (2 patients). A posterior leaflet prolapse was associated in three cases, whereas one patient had a concomitant restricted motion of the posterior and septal leaflets due to the tethering effect produced by the right ventricular dilatation.

In eight patients tricuspid regurgitation was due to multiple leaflet prolapse because of mixomatous degeneration of the valve. In particular, prolapse of all three leaflets was observed in three patients, of two leaflets in other three and an isolated large prolapse of the anterior and septal leaflets could be found, respectively, in the remaining two cases. Prevalence of individual leaflet prolapse was 87% (7 patients) for the anterior cusp, 75% (6 patients) for the septal and 50% (4 patients) for the posterior. All eight patients with degenerative tricuspid insufficiency had concomitant mitral valve pathology as well. Finally, in one single case, tricuspid regurgitation was caused by annular dilatation and tethering of all leaflets because of significant right ventricular enlargement in the setting of ischemic dilated cardiomyopathy. In all the 14 patients reported in this series, the tricuspid annulus was significantly enlarged and some degree of right ventricular overload was present (mean right ventricular end-diastolic dimension 56 ± 8.4 mm, range 47–64 mm) whereas right ventricular dysfunction was evident only in two cases. Symptoms usually included dyspnea and fatigue.

2.2. Surgical technique

A median sternotomy was performed and, after aorto-bicaval cannulation, cardiopulmonary bypass was instituted at mild hypothermia. The aorta was cross-clamped and cold blood cardioplegia was delivered antegradely. In the nine patients requiring concomitant mitral valve surgery, the mitral valve was approached through the left atrium. Mitral valve repair was performed in six patients, whereas mitral valve replacement was necessary in the remaining three. In all patients the tricuspid valve was exposed through a conventional oblique right atriotomy and the valve anatomy and mechanism of regurgitation were carefully assessed.

The new surgical approach that we adopted in these difficult situations consisted of stitching together the middle point of the free edges of the tricuspid leaflets producing a clover shaped valve (Figs. 1 and 2). In two cases, because of the intraoperative finding of a small accessory leaflet between the septal and the posterior cusps, the adoption of this approach produced a valve with a characteristic ‘four-leaflet clover’ configuration. In all cases repair was performed during cardioplegic arrest and using a 5.0 polipropylene suture without pledges. A Carpentier

Table 1

Pre-operative clinical characteristics of the patients

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean ± SD)</td>
<td>57 ± 17</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>8/6</td>
</tr>
<tr>
<td>TR aetiology (n,%):</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>5 (35.7)</td>
</tr>
<tr>
<td>D</td>
<td>8 (57.1)</td>
</tr>
<tr>
<td>DCM</td>
<td>1 (7.1)</td>
</tr>
<tr>
<td>Chronic atrial fibrillation (n,%):</td>
<td>1 (7.1)</td>
</tr>
<tr>
<td>NYHA class (%)</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>4 (28.5)</td>
</tr>
<tr>
<td>III</td>
<td>10 (71.4)</td>
</tr>
<tr>
<td>Concomitant MV disease (%)</td>
<td>9 (64.2)</td>
</tr>
<tr>
<td>EF (%)</td>
<td>57 ± 8.8 (35–65)</td>
</tr>
<tr>
<td>SPAP (%)</td>
<td>62 ± 25 (48–100)</td>
</tr>
</tbody>
</table>

TR, tricuspid regurgitation; T, post-traumatic; D, degenerative; DCM, dilated cardiomyopathy; SPAP, systolic pulmonary artery pressure.

Fig. 1. Schematic drawing of the final shape of the tricuspid valve after the ‘clover technique’.
tricuspid ring (number 34 or 36) or a Taylor complete flexible ring (number 29 or 31) was always implanted to correct the annular enlargement and stabilize the repair. The choice of the ring was exclusively based on the surgeon’s preference. Following the correction, saline was injected into the right ventricle to test valvular competence. Other cardiac procedures were associated as needed: radiofrequency ablation of atrial fibrillation (1 patient), correction of ostium secundum atrial septal defect (1 patient) and closure of a patent foramen ovale (1 patient). Mean cardiopulmonary bypass time and aortic cross clamp time were 60±12.9 and 42±6.4 min, respectively. Considering the patients undergoing isolated tricuspid repair only, mean cardiopulmonary bypass and ischemic times were 32±6.3 and 23±7.4 min, respectively.

After weaning from cardiopulmonary bypass, tricuspid valve function was evaluated by transesophageal echocardiography.

2.3. Follow-up

Before discharge, all patients underwent control transthoracic echocardiography. Oral anticoagulation was prescribed for 3 months after repair. Follow-up information was obtained for all hospital survivors through out-patient clinic visit and echocardiography and was 100% complete. Stress echocardiography was performed in two patients to assess the behaviour of the tricuspid valve under stress condition. The mean follow-up duration was 12±6.3 months (range 1–22 months).

2.4. Statistical analysis

The results are expressed as mean ± SD. Statistical significance was obtained by two-tailed paired t-test for continuous variables.

3. Results

Hospital mortality was 7.1% (1/14). The patient who died was the one affected by ischemic dilated cardiomyopathy. After successful mitral valve replacement with a bioprosthesis and tricuspid valve repair, she unfortunately suffered from cerebrovascular event and was, therefore, unweanable from the mechanical ventilator. Post-operative echocardiogram, performed about 3 weeks after surgery, showed only trivial tricuspid regurgitation.

All the other patients survived the operation and were discharged within 6 days after an uneventful post-operative course. Mean intubation time was 17±5.9 h and mean ITU stay 22±7.5 h. Post-operative complications included one case of bleeding requiring surgical re-exploration and one episode of atrial fibrillation successfully treated by amiodarone infusion. There were no late deaths. At discharge, tricuspid regurgitation was absent in six patients (46%) and mild in the remaining seven. At the latest follow-up all survivors were asymptomatic (NYHA I) and tricuspid insufficiency was absent in five cases (38%), mild in seven patients (53%) and moderate in one (7%). Mean tricuspid valve area and gradient were 4.2±0.4 cm² and 2.7±1.4 mmHg, respectively. A significant reduction of the right ventricular end-diastolic dimensions was noted as well (from 56±8.3 to 44±6.1 mm, \(P<0.001\)). All patients were in sinus rhythm including the one submitted to radiofrequency ablation of chronic atrial fibrillation.

3.1. Exercise echocardiographic evaluation

Although low mean tricuspid gradients have been measured at rest after the application of the clover technique (2.7±1.4 mmHg), the main potential drawback of this approach is the risk of creating a stenotic tricuspid valve, particularly during exercise. Stress echocardiography was, therefore, adopted to assess the behaviour of the tricuspid valve under stress condition. Although our plan is to extend this type of evaluation to all patients, so far only two of them have been studied. Both had degenerative tricuspid valve prolapse and underwent concomitant mitral valve replacement (patient 1) and mitral valve repair (patient 2). A bicycle ergometer stress test was performed in supine position with a 10 W incremental step every 1 min reaching at least 80% of the age-predicted heart rate. The total tricuspid valve area was calculated as the sum of the three individual orifice areas measured in parasternal short axis view. Hemodynamic data at baseline and at peak of the stress are reported in Table 2. Heart rate, systolic blood
pressure, stroke volume and cardiac output increased during physical exercise. At peak of the exercise, no symptoms occurred, the mean diastolic tricuspid gradient remained below 3 mmHg and the planimetric tricuspid valve area was larger than 4 cm² in both patients. The systolic pulmonary artery pressure remained within normal ranges.

4. Discussion

Tricuspid regurgitation due to complex lesions like prolapse/flail of multiple leaflets and/or restricted motion of one or more cusps represents a challenging surgical problem and has been usually treated by valve replacement. Occasionally demanding reconstructive procedures have been carried out, not unusually with suboptimal results. In this preliminary experience the clover technique proved to be a reproducible and effective approach for the treatment of tricuspid insufficiency due to complex mechanisms. Indeed, valvular competence was always restored and the repair was never restrictive either at baseline or under stress conditions.

From an aetologic point of view, blunt chest trauma and degenerative disease of the tricuspid valve are the two pathologic conditions most commonly associated with these findings. Right ventricular dilatation, particularly in the context of dilated cardiomyopathy, is another setting in which tricuspid regurgitation may not be amenable of repair by simple annuloplasty because of the tethering effect produced by the enlargement of the right ventricular chamber. Indeed, all patients reported in this series, had either severe post-traumatic or degenerative tricuspid insufficiency. The only exception was represented by one case of tricuspid regurgitation in the context of ischemic dilated cardiomyopathy.

4.1. Post-traumatic tricuspid regurgitation

Post-traumatic tricuspid regurgitation is a rare complication of blunt chest trauma with about 120 cases reported so far in the literature, usually involving young patients. Chordal rupture, followed by rupture of the anterior papillary muscle, tear of the leaflets and cusp retraction are the most frequently reported injuries. Progressive dilatation of the tricuspid anulus occurs in most cases. The majority of the patients described have been treated with valve replacement but, more recently, repair of the native valve has been attempted to avoid prosthesis-related complications and to better preserve the geometry and function of the right ventricle. The surgical techniques adopted have been tailored to the specific anatomical lesions encountered at the time of surgery. Artificial chordal implant, quadrangular resection of the flail segment or chordal transposition have been used in presence of chordal rupture. Muscle reimplantation has been performed in case of papillary muscle disruption [2,3]. These conventional reconstructive procedures, however, have allowed successful repairs in less than 40% of cases. Indeed, the surgical correction of complex lesions by classical techniques, besides being technically demanding, is made particularly difficult by the flimsy nature of the tricuspid apparatus [4]. Therefore, several unsuccessful attempts at papillary muscle and chordal repair, followed by tricuspid valve replacement have been described. Holper reported on five patients operated on for traumatic tricuspid insufficiency in whom a primary valvular reconstruction was successful only in one case, whereas it failed in the remaining four making the replacement of the valve unavoidable [5]. Richard described nine patients with traumatic rupture of the anterior papillary muscle of the tricuspid valve, who underwent surgical correction: valve repair was considered possible in just one of them [6]. In the Mayo Clinic experience, out of 13 patients with traumatic tricuspid regurgitation, valve repair was considered feasible in five cases (38%) and unsuitable in the remaining eight (62%) [7]. These data confirm that correction of longstanding post-traumatic tricuspid regurgitation by conventional reconstructive methods is not always feasible or is associated with significant residual valve incompetence. Our own initial experience in this field, published in 1996, is consistent with this finding [2]. The recent application of the clover technique, instead, allowing a functional rather than an anatomical repair, has always been able to restore a perfect competence of the tricuspid valve, confirmed at 1-year follow-up, despite the complexity and multiplicity of the lesions treated [1].

4.2. Tricuspid valve prolapse

Tricuspid valve prolapse has remained a poorly defined entity, which is most commonly associated with mixomatous degeneration of the mitral valve although isolated prolapse of the tricuspid cusps without concomitant mitral
disease has been reported as well [8–12]. In the majority of cases the tricuspid regurgitation is not severe enough to warrant surgical intervention and, therefore, it has been described in several post-mortem studies [13,14] and only in a few clinical papers [15]. In one large autopsy series [16], the prevalence of this finding ranged from 0.3 to 3.2%. In another post-mortem study [13], tricuspid valve prolapse was present in 7 (15.6%) of 45 patients with pure tricuspid regurgitation. Usually all three leaflets of the tricuspid valve, or at least two of them, are prolapsing. Tei and co-workers [17] assessed the tricuspid valve by 2D echocardiography in 14 patients with tricuspid valve prolapse and in 16 normal subjects. Prolapse of all three leaflets was observed in six patients, of two leaflets in five and of one cusp in three cases. Brown assessed with 2D echocardiography 143 subjects recognizing a tricuspid valve prolapse in 13 (9%) of them, usually involving two or three cusps [18]. In these situations, similar to traumatic tricuspid regurgitation, annuloplasty alone would not be likely able to restore adequate valve competence or might be associated with suboptimal results. If the prolapsing area is small and involves just one leaflet, a simple resection of the flap segment can be performed [8]. This strategy, however, might not be successful if the prolapse is not limited to a localized portion of one cusp but rather involves two or three leaflets as it was in our series. Therefore, on the base of the experience acquired with the clover technique in case of traumatic tricuspid regurgitation, this approach was added to the ring annuloplasty in all these patients and satisfactory results were obtained either immediately or at follow-up.

### 4.3. Tricuspid regurgitation in dilated cardiomyopathy

Finally, this surgical approach seems to be potentially effective also in case of tricuspid regurgitation due to tethering of the leaflets secondary to severe right ventricular dilatation. It should be stressed that, in this particular setting, the clover technique was applied just in one case and, although the competence of the valve was perfectly restored, a word of caution in terms of its effectiveness in this context is necessary until more cases have been enrolled and treated.

We are aware that the limitations of this study are numerous. It is an observational report with a small number of patients and a short-term follow-up. Many more cases and a significantly longer period of observation are required to validate the effectiveness and durability of this promising procedure. Nevertheless so far valvular competence was always restored and the stress echocardiography data, although related only to two patients, seem to indicate that the artificially created clover valves follow a physiologic behaviour and functional tricuspid stenosis does not develop during physical exercise. Moreover, in our experience with the edge-to-edge technique for mitral valve reconstruction, we have shown that the double orifice repair does not cause mitral valve obstruction either at baseline or during exercise and does not affect valve hemodynamic and valve reserve [19]. It seems reasonable to speculate that, since a valve stenosis problem was never detected on the left side of the heart, this type of complication appears to be rather unlikely to occur on the right side, in presence of lower pressure conditions and post-operative tricuspid area > 4 cm².

We, therefore, regard the clover technique as an effective approach, which can be a useful addition to the surgical armamentarium in case of complex tricuspid valve lesions either post-traumatic, degenerative or associated with right ventricular dilatation or dysfunction.

### References


Appendix A. Conference discussion

Dr U. Giedrius (Vilnius, Lithuania): Why do you call this a novel technique?

Dr DeBonis: Well, so far we didn't find this technique reported in the literature and, therefore, we thought it was quite a novel approach.

Dr Giedrius: So I would like to show my first slide, okay? First slide, please. It is a comment slide, please.

(Slide) I did this a half year ago before your team started. This is proof in Cardiovascular Surgery, 'The First Triple Orifice Repair For Tricuspid Insufficiency, First Experience From Vilnius Clinic,' and I am the surgeon who performed it. It is 13 cases. And before that, in 2000, I reported that in our local paper.

(Slide) This is a local paper of Lithuania Medicine where I described this technique, 13 cases, and the first operation was performed by myself on 22nd April of 2000. And I regret deeply because I twice sent paper to European Association for reporting and I was refused each time. So it is a little offensive for me.

(Slide) This is what it was entitled in a Budapest meeting, and next one, (Slide) This is what it was entitled in a Budapest meeting, and next one, is the procedure I performed in 2000, April 22. You see, I do it a little differently.

My first 11 patients went on different surgery, putting in pledgets, and I had good results. But then in the later follow-up, now more than 3 years and a half, I found those patients having complaints because of highly protruding valve when we have a huge prolapse of the mitral or tricuspid valve. They have palpitations, they have a feeling like something is inside.

So I went deeper, inventing two more approaches.

First of all, I put in the deep pledgets on the opposite side from the ventricle side on the leaflets and as deep as to try to level the coaptated area to the annulus, regarding the annulus, and it seemed to be very good. But then in the last four cases I tried to harness or to curb or to anchor the central coapted portion, because it still protrudes, and it is very difficult to judge at which level it should be stopped.

So through the apex of the left ventricle, if you go into the mitral valve, or through the apex of the right ventricle if you are correcting tricuspid valve, you put a 3–0 or 4–0 Gore-Tex suture, you correct the valve in this fashion, as we do, as you do, and then you anchor on this ligature the valve, and then you put the stitch outside the heart and you close the chambers. You will have helped the patient, and by doing this, you can readjust at the proper level, at the level you desire, or at least at the level that the small jets are not present anymore and the prolapse is corrected. I did it in four cases. I suggest to all of you to do the same and to try to implement this procedure.

Dr Hagl: Thank you very much. First, let me ask, is Dr Alfieri in the auditorium? Ottavio, do you want to comment on it first?

Dr O. Alfieri (Milan, Italy): We did not find your original paper in the literature and therefore we wrongly considered this method a novel technique. I congratulate you for being the first.

Dr Giedrius: I love the paper and I suppose that it should be published, because if I am taken for oral presentation, it is here to be published. They returned me back, and for two years it was coming to and fro, to and fro all the time, trying to tell me that this is wrong, this is a foolish operation.

Dr DeBonis: Well, I want just to congratulate our colleague and say that we really did not find in the literature the paper he mentioned.

Dr Hagl: Can you please focus on the question concerning the technique.

Dr DeBonis: Concerning the technique, we don't use pledgets to put the stitch in. We have, as you probably know, quite a large experience with the edge-to-edge technique on the mitral side. We didn't have any case of rupture, therefore we didn't think it was necessary to put pledgets to reinforce a suture in the right side of the heart where the pressures are even lower than on the left side. The pledgets can just increase the risk of infection and in our hands, we did not experience any problem using the technique as it has been described now.

Dr R. De Simone (Heidelberg, Germany): Patients with severe tricuspid regurgitation have a certain degree of right chamber enlargement, and what is your strategy in patients with right ventricular enlargement if you do not use an annulus? Don't you think that you are missing the opportunity to reshape down the right ventricle by avoiding using an additional annulus?

Dr DeBonis: Yes.

Dr DeBonis: We always used ring annuloplasty in our patients undergoing the clover technique.

Dr De Simone: Even in the traumatic patient where you have an acute tricuspid regurgitation?

Dr DeBonis: No, that was not acute. The duration of tricuspid regurgitation in the post-traumatic cases ranged form 5 to 25 years, so it was a long-standing, post-traumatic, chronic tricuspid regurgitation, and we always used an annuloplasty ring to remodel the annulus as well.