Surgical closure of muscular ventricular septal defects using double umbrella devices (intraoperative VSD device closure)

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Abstract

Objectives: Surgical closure of some muscular ventricular septal defects has been proven to be difficult. In order to simplify the surgical technique we have used intraoperatively Rashkind double umbrella devices to occlude muscular ventricular septal defects. Methods: On the basis of haemodynamic and echocardiographic study five children aged 4, 6, 7, 14 and 41 months were considered suitable candidates for intraoperative closure of muscular ventricular septal defects (midmuscular in three cases, apical in two) by Rashkind devices. Three of them had previously undergone pulmonary artery banding at 10, 11 and 41 days, respectively. During hypothermic cardiopulmonary bypass a delivery system was introduced across the tricuspid valve into the right ventricle and then passed through the ventricular septal defect; the distal umbrella of a 17 mm device was opened in the left ventricular cavity; a traction was applied to the introducer and the proximal umbrella was opened on the right side straddling the interventricular septum; the device was then secured on the right side by few stitches. In one case because of the wide diameter of the ventricular septal defect two umbrellas were used. The surgical procedure was completed with debanding and/or closure of other defects close to the aortic or tricuspid valve. Results: Immediate results, tested by epicardial or transesophageal echo, showed a minimal residual shunt in 4 patients and a moderate shunt in one. No early deaths occurred. A complete atrioventricular block developed in 1 patient who had an additional perimembranous defect closed with a prosthetic patch: a permanent pace maker was inserted 3 months after the operation. There was a late death for untractable right ventricular failure in 1 patient who had a large residual shunt erroneously considered moderate. In this patient, the size of the defect was underestimated both preoperatively then intraoperatively. The four survivors are doing well with no signs of hemodynamically significant residual shunts. Conclusions: The use of Rashkind umbrella devices for closing intraoperatively muscular defects can be helpful to standard surgical techniques when technical problems make patch closure difficult. Its use avoid the need of left ventriculotomy. Careful definition of the size of the defect is mandatory to select suitable candidates. © 1997 Elsevier Science B.V.

Keywords: Ventricular septal defect; Surgery; Assist device; Heart disease; Congenital

1. Introduction

Despite improvements in diagnostic accuracy [10] and surgical techniques; closure of muscular ventricular septal defects (VSDs), multiple or isolated, situated in the low or apical part of the interventricular septum, is still associated with significant long term morbidity and mortality [3,4,7].

Different surgical approaches have been suggested, some of them requiring either a right or left ventriculotomy [8,9,12]. However, technical difficulties and unsatisfactory results have prompted surgeons to search for new strategies. Closure of muscular defects with biologic glue or (requiring a collaborative support to interventional cardiology) intraoperative use of devices have been reported [2,5].

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Table 1
Summary of patients data

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</table>

PAB, pulmonary artery banding; VSD, ventricular septal defect.

Our group, in order to obtain a simple technique to be used when surgical closure of muscular VSDs results to be difficult, has utilised intraoperatively, in 5 patients, Rashkind double umbrella devices.

2. Patients and methods

From December 1993 to January 1995 five children aged 4, 6, 7, 14 and 41 months were considered suitable candidates for intraoperative device closure of muscular ventricular septal defects (Table 1).

In other institutions three children had previously undergone pulmonary artery banding associated in two cases to aortoistmoplasty at 10, 11 and 41 days of age. Elsewhere 1 of these patients, at the age of 9 months, underwent to a surgical attempt of closure of multiple muscular ventricular septal defects and removal of the pulmonary artery banding. The procedure was unsuccessful and the child was rebanded 4 days later.

By echocardiography and angiocardiography VSDs location and size were determined in all patients except one (4 months old) where echocardiographic data were thought sufficient for the correct definition of VSDs size and location. Intraoperatively all patients underwent transesophageal or epicardial echo for final assessment of VSDs (Fig. 1).

One patient had a single apical septal defect (low trabecular septum); 4 patients had two VSDs: one muscular in the mid trabecular septum and one perimembranous infundibular in 2 patients; both in the mid trabecular septum in 1 patient; one apical and one in the mid trabecular septum in 1 patient.

Hypothermic circulatory by pass was used for all operations. Myocardial protection was provided by antegrade intermittent cold crystalloid cardioplegia. The right atrium was opened longitudinally and, through the tricuspid valve, the location of the VSDs was confirmed with direct visualisation and instrument probe of the ventricular septum. In one case it was necessary to open the aorta and the ventricular septum was probed from the left side.

The cardiac surgeon introduced the delivery system across the tricuspid valve into the right ventricle and passed through the VSD. The cardiologist delivered the device. The distal umbrella of a 17 mm Rashkind device was opened on the left side of the septum; a traction was applied to the introducer and the proximal umbrella was opened in the right ventricular cavity. The device was then secured on the right side of the septum by two stitches around two of its arms.

In 4 patients additional VSDs were closed: with a Sauvage patch in two of them, with stitches and pledgets in two others. The procedure was completed in 3 patients by debanding and subsequent enlargement of the pulmonary arteries with autologus pericardium.

Adequacy of closure was assessed by direct inspection, saline infusion in the left ventricle and postpump measurement of right atrial and pulmonary artery oxygen saturations. In all patients transesofageal or epicardial echo and colour Doppler were used, after by pass discontinuation, to determine persistency of residual shunts and position of the devices (Fig. 2).

In 1 patient the transesofageal echo (TEE) revealed the persistency of a massive residual shunt associated with a partial dislodgement of the umbrella toward the left ventricular cavity. By pass was resumed and, through the tricuspid valve, the umbrella was firmly fastened and retracted in a correct position straddling the interventricular septum. The umbrella was then secured with two additional stitches to the right side of the septum. Whatever it was evident that the size of the...
umbrella was not sufficient to totally occlude the large VSD leaving a residual communication in the apical portion of the septum. An additional device was introduced in the residual VSD and, with the usual technique, opened across the defect. Fibrine glue (Tissucol, Immuno-France, Orly, France) was applied on the right surface of the opened umbrellas. By pass was interrupted and a transesophageal echo showed a fairly good result with only a moderate residual shunt persisting.

3. Results

No early deaths occurred.

Immediate results tested intraoperatively by epicardial or transesophageal echocardiography showed a minimal residual shunt in 4 patients. In 1 patient the shunt was moderate.

The postoperative course was uneventful in 4 patients. The patient, who had a moderate shunt around the two umbrellas had a postoperative course characterised by a low cardiac output syndrome and need massive inotropic support and prolonged mechanical ventilation. Her condition progressively improved and the child was extubated on postoperative day 8. Routinely all patients underwent echocardiography during the first postoperative days and before discharge.

At discharge 3 patients had a minimal residual shunt and one moderate. A patient had his minimal residual shunt, detected intraoperatively, disappeared in the third postoperative day. Ventricular function was good in 4 patients except in one, with the moderate shunt, who showed a hypokinetic interventricular septum.

Follow up—3 months after the operation a patient necessitated the insertion of an epicardial pace maker because of a grade 3 atroventricular block. This child had a perimembranous infundibular VSD closed with a prosthetic patch.

A late death occurred 5 months postoperatively. This child, who had two umbrellas, had a moderate shunt post operatively. She returned 4 months postoperatively with signs of right ventricular failure. The right ventricle showed massive hypertrophy with a small cavity. An echo-Doppler study showed a moderate residual shunt. According to her clinical conditions an hemodynamic study was planned. After 1 month, the child was admitted on emergency base in poor general conditions with severe right ventricular failure. An emergency cardiac catheterisation was scheduled. At induction of anaesthesia the child arrested and resuscitation manoeuvres failed.

Autopsy revealed an enlarged right atrium with grossly dilated tricuspid valve. The right ventricle had a small cavity with massive hypertrophic walls; on the right side the superior part of the devices was endothelised while the inferior part was not covered by an endothelial membrane suggesting a persistent residual turbulent flow. The devices showed to be correctly positioned straddling the interventricular septum but a large residual VSD was present between the apex of the heart and the inferior edge of the positioned devices. The left ventricle had a normal shape and size. One of the arms of the device embedded the free wall of the left ventricle (Fig. 3).

The follow up period range between 10 and 21 months. All the four survivors are in good general conditions and all of them are in NYHA class 1. Two patients have no signs of residual shunts at echo Doppler study; 2 others patients have ‘micro’ residual shunts hemodinamically insignificant.

Fig. 2. Epicardial ultrasonic image showing the correct position of the device straddling the interventricular septum. Patient No. 4. RV, right ventricle; LV, left ventricle; CPB, cardiopulmonary by pass.

Fig. 3. Autopsy specimen. Interventricular septum from the left side. The devices are positioned across an huge apical ventricular septal defect. A residual defect is present in the apical portion of the septum below the distal device. One of the arms of the device is embedded in the ventricular wall.
4. Discussion

Closure of muscular VSDs, multiple or isolated, situated in the lower or apical part of the interventricular septum still remain a difficult challenge.

In some instances a right atrial approach can allow a proper visualisation and allows a correct closure of the defect; in other cases a right ventriculotomy is required because of the presence of several trabeculae carnea [8].

More frequently low trabecular (apical) muscular VSDs require a left ventriculotomy [9,12]. In some instances a combined right and left ventriculotomy have been used [12].

Despite improvements in angiographic, echocardiographic diagnosis and in surgical techniques the mortality and long term morbidity still are significant [3,4,7]. Mortality and morbidity are frequently due to significant residual VSDs or ventricular disfunction.

In 1980 Kirklin and associated presented a series of 29-cases with 14% mortality rate and 28% reoperation rate for residual shunts [4]. Serraf and associates, in 1992, reported 130 cases of multiple VSDs with an operative mortality of 7,7%. Overall mortality was 10%.

Residual VSDs were the cause of death in 7 patients out of 13 patients [7].

Left ventriculotomy seems to affect significantly the overall mortality and morbidity [7]. Iliana and Coll found, at an average of 5 years follow up, significant late residual abnormalities (residual VSDs, moderate to large apical aneurysm and moderate to severe global left ventricular disfunction) in 50% of patients who underwent left ventriculotomy for VSD closure [3]. These unsatisfactory results have prompted surgeons to search for new strategies to occlude muscular defects of the interventricular septum.

Leca and associated have recently utilised in 15 patients Fibrine glue for closing small muscular VSDs [5]. Hospital mortality rate was 6% and, at follow up ranging from 3 months to 3 years, there were no reoperations and the interventricular septum was tightly close in 8 patients. Five patients had only 'micro' VSDs perceptible with echo Doppler. In Leca's series all the larger VSDs were closed with either a pericardial patch or a pericardial patch lined with Dacron fabric. This innovative technique still necessitated some clinical investigation because of the concern about its adaptability for closing big muscular VSDs and the possibility of Fibrine Glue systemic embolisation.

Results of transcatheter closure of congenital muscular defects as an isolated or a preoperative procedure are promising and can be considered a valuable alternative to surgery. [1] However this approach is not always suitable for small infants. It exposes small children to the risk of peripheral vascular injury and to radiation induced complications [11].

Moreover in many cases where muscular VSDs are associated with perimembranous VSDs or when the muscular VSDs are associated with more complex malformations, open heart procedure are not avoided.

Intraoperative device closure of VSDs has been described in 9 patients by Fishberger et al., 1993 [2]. Patient population was highly unfavourable because of the complex cardiac lesions or the poor preoperative conditions. There were three early deaths and only one death was attributed to the procedure itself. The other 2 patients who died were in moribund state preoperatively. There was an unexpected late death. Patients, 2, had significant residual shunts that required surgical removal of the device followed by patch closure in 1 patient and transcatheter closure in the other one. TEE or epicardial echo were not used intraoperatively to assess persistency of residual shunts or devices position. However it was not shown clearly in this study the correlation between the associated cardiac anomalies and the surgical outcome. Only 2 patients in this series had multiple muscular VSDs as an isolated anomaly and both did well.

We have chosen the intraoperative device closure only for patients who had muscular VSDs, multiple or isolated, and where open heart procedures had to be performed because the presence of associated perimembranous VSDs and pulmonary artery banding.

Preoperatively VSDs localisation was achieved by angiocardiography and echocardiography in all patients except one where echocardiography was considered sufficient.

The placement of the device through the tricuspid valve was technically feasible without difficulties with the aid of the delivery system commonly used percutaneously and no right or left ventriculotomy was required. Intraoperative epicardial or transesofageal echo colour Doppler was useful in assessing residual defects and the correct position of the device. The importance of an appropriate preoperative and intraoperative diagnosis as well as the correct intraoperative evaluation of residual shunts is mandatory. In the patient that died 5 months postoperatively the residual shunt was clearly underestimated as well as the diameter of the apical VSD. Very likely the exact evaluation of the size of the defect would have discouraged us to use this technique. As indicated by Lock et al. the stretched diameter of a defect should not be larger than 50–60% of the stated diameter of a standard Rashkind double umbrella device [6]. This rule defined for transcatheter closure of VSD should be applied also for intraoperative use of umbrella devices when closing muscular VSDs.

Despite the fact that the risk of embolisation of the device is in this technique substantially abolished by the possibility to secure it with stitches to the interventricular septum, the partial dislodgement of the device as well as the persistency of significant residual shunts, due
to a mismatch between the diameter of the VSD and the diameter of the device, are possible.

The disappearance of residual shunts early or late postoperatively indicates a possible device leakage for 24–48 h postoperatively or perhaps closure of same minimal residual defects with time. This possibility should not allow the acceptance of more then minimal shunts at the intraoperative T.E.E; on the contrary by pass should be resumed and the defect inspected once again.

In conclusion in patients with muscular VSDs this technique can be used in association with standard surgical therapy when surgical problems make patch closure difficult and associated with high morbidity and mortality. Its use can avoid the necessity of a left ventriculotomy. Adequate definition of the size of the defect is mandatory to select suitable candidates. Probably using smaller devices and with the development of more technically adequate delivery system the intraoperative closure of some muscular VSDs, even in small infants and neonates, will be possible as a primary procedure reducing the need of pulmonary artery banding in such situations.

References


Appendix A. Conference discussion

Dr Tomas Tlaskal (Prague, Czech Republic): I would like to ask you about your surgical strategy during surgery. Are you going straight forward to use the umbrella device or do you try to close the defect first surgically by a patch? And do you think that it is always possible to use this technique, or what are the limitations of the use of this umbrella device?

Dr Murzi: Dr Tlaskal, it was decided before the operation which VSD was to be closed by the device and during the operation we tried to close that particular VSD using the umbrella. The technique is easy but a correct selection of suitable candidates is mandatory. What is more difficult is to find the VSD. When you have found the defect it is nearly always possible to close it using the device.

Dr Giovanni Stellin (Padova, Italy): As it was pointed out on Sunday at the Postgraduate Course, intraoperative multiple VSDs closure with double umbrella device seems to be the procedure of choice for those children who present early in life with severe heart failure. I would like to address to you a couple of questions: (1) Have you ever divided the moderator band to close apical VSDs as suggested yesterday by Claude Planche? (2) How do you check the position of the distal umbrella once it has been opened in the left ventricle? In our case, we managed to check the position of the distal device through a large subaortic VSD. Would you suggest some other techniques like inserting a fiberoptic device through the aortic valve in order to assess whether or not the umbrella has properly opened in the LV?

Dr Murzi: Dr Stellin, we did not divide the moderator band. Dividing the moderator band visualisation of the VSD can be better but you probably also enlarge the diameter of the defect and this is a disadvantage rather than an advantage using this technique. About your second question we did not check the umbrella opening. We took some measures on the wire and looking at the previously marked distances we knew when the umbrella was open. Considering the way of opening of this type of device I think there are only theoretical risks of entrapping some anatomical components of the left ventricle.

Dr Rodolfo A. Neirotti (Grand Rapids, Michigan). I think when one closes the VSD every effort should be made to visualize the edge of the VSD completely. Quite often these muscular apical VSDs are divided by a muscular band. I strongly support what Dr Giovanni Stellin mentioned, that in many cases it is very useful to divide this muscular band in order to visualize the VSD completely and for placement of the patch in the right place. Perhaps this could be something to consider when you are using this technique.

Dr Murzi: Dr Neirotti, using a patch you must have the definition of all the borders of the VSD because you are closing a defect. Using an umbrella you are occluding. I think it is something different. You put the device inside the defect and it will occlude everything. Once more the correct proportion between the diameter of the VSD and the diameter of the device is mandatory to allow the complete occlusion and to avoid the possibility of dislodgement of the device itself.

Dr Francis Fontan (Bordeaux, France): The main goal is to avoid opening the left ventricular cavity. But I am aware of some other experiences. I remember, Madame Leca, that you presented in Vienna last year your results with another kind of approach. Could you comment on that?
Dr Françoise Leca (Paris, France): Congratulations, Dr Murzi, I agree with you and with Dr Fontan. I think it is very important to avoid opening the left ventricle. So we described some years ago a technique similar to your technique using a fibrin seal.

We operated on 15 patients. With this technique 53% of the patients had a Swiss cheese.

The technique is safe and very simple, through the right atrium, without left ventriculotomy. After closure of the large perimembranous VSD with a pericardial patch, and infundibular VSD, with pledgeted suture, all of the muscular VSDs are closed with Tissucol. The needle was driven in through the VSD until the left ventricle was entered, then carefully withdrawn while the Tissucol was injected. The operating field must be dry. The setting of the glue was very fast.

The results are good. We have one early death on the second day and one late death at 7 months in a child with a very complex cardiopathy. The morbidity: one transient hemiplegia, probably because of embolus of a little clot of glue. This hemiplegia was completely regressive. We have no reoperation. And among the survivors, eight had a perfectly tied ventricular septum and five had a micro VSD only perceptible at colour Doppler. There is no reoperation; this is an important feature.

So, since 1986, for all the patients even very small babies, fibrin glue was used with a satisfactory result for closure of muscular VSD, Swiss cheese.

Dr Murzi: Dr Leca's technique is very innovative and useful. Using different techniques we are trying to avoid opening the left ventricle. This is the goal. Adequately standardised both our techniques can probably help us to solve the difficult problem of muscular VSDs.