The Beating Heart Approach is Not Necessary for the Dor Procedure

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Background. **Ventricular reconstruction using the Dor technique has been demonstrated to improve outcome in patients with dilated left ventricles. It has been suggested that a beating heart approach improves ventricular function by allowing the surgeon to palpate that part of the ventricle to exclude.**

Methods. **We performed a retrospective analysis of patients who underwent an endoventricular circular patch plasty (Dor procedure) between 1998 and 2001. All patients who received ventricular restoration, with or without revascularization or valve repair, were included in the analysis. Discrete left ventricular aneurysms were excluded. Patients were divided into two groups: group 1 (n = 15) underwent ventricular reconstruction with the beating heart technique, whereas group 2 (n = 38) underwent restoration with the aorta cross-clamped. Clinical and hemodynamic data were collected from medical records and computerized databases and compared between the two groups.**

Results. **Fifty-three patients underwent endoventricular circular patch plasty. All patients had enlarged ventricles (echocardiogram demonstrating unidimensional end-diastolic diameter ≥ 6.0 cm) and echocardiographic evidence of severe left ventricular dysfunction (mean ejection fraction: group 1 = 21.4%; group 2 = 23.4%). No operative mortalities occurred in either group and all patients were discharged home alive (mean postoperative hospital stay 8.3 days [6 to 22 days]). All patients had improvement in left ventricular function with mean postoperative left ventricular ejection fraction of 36.9% (25% to 52%) in group 1 versus 38.1% (31% to 50%) in group 2, $p = 0.081$. Ventricular arrhythmias occurred in 5 of 15 group 1 patients and in 9 of 38 group 2 patients. Two patients in the entire cohort (1 patient in group 1, and 1 patient in group 2) had at least one readmission within 12 months with evidence of heart failure. The group 1 patient went on to successful transplant 11 months later, whereas the group 2 patient died 10 months later.**

Conclusions. **These results demonstrate that the Dor technique of ventricular restoration significantly improves left ventricular function and the beating heart approach provides no additional advantage over continuous aortic cross clamping.**

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Over the last several decades various techniques of ventricular reconstruction have been described as a viable option for patients with postinfarct ventricular aneurysms [1–3]. More recent investigators have described modifications of endoventricular circular patch plasty as a surgical alternative to ischemic cardiomyopathy [4]. The goal of this therapy is to restore ventricular shape and function and subsequently improve left ventricular (LV) function.

In ischemic cardiomyopathy, especially with previous anterior infarction, the anterior wall and often the septum are replaced with fibrous scar or akinetic muscle. These are often patients without discrete ventricular aneurysms that have large, dilated left ventricles leaving the heart in more of a spherical rather than elliptical shape. The initial concept of ventricular reconstruction was to exclude the noncontractile areas of the ventricle or septum using a patch or direct suture and subsequently restore the normal elliptical shape of the ventricle [5, 6].

Most published descriptions of ventricular restoration describe correct placement of the Fontan or exclusion stitch [3, 5, 7]. This stitch placement is often achieved by removing the aortic cross-clamp and allowing the heart to beat. Buckberg [8] described the beating heart technique, which emphasizes digital palpation to allow the surgeon to distinguish between nonfunctional, noncontracting free wall and healthy muscle in the border zone. This fine distinction using digital exam is difficult and makes suture placement more complex. We believe the size of the ventricle after the procedure can be determined by preoperative planning based on ventriculograms or transesophageal echocardiography. Over the last several years we have started to leave the aortic cross-clamp on during placement of the exclusion stitch in a location that is determined by preoperative imaging. Although this technique may add to the total ischemic time, we hypothesized there was no difference in outcome if the aortic cross-clamp was left on while nonfunctional muscle is being excluded.

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Material and Methods

We performed a retrospective analysis of all patients who underwent endoventricular circular patch plasty (Dor procedure) [3] between 1998 and 2001 at the University of Virginia Health Science Center. The medical records of 53 patients were reviewed. All patients who received ventricular restoration for dilated ventricles were included in the study. Patients with discrete LV aneurysms (areas of LV dyskinesia) were not included in this analysis. Indication for ventricular restoration was severely dilated cardiomyopathy (echocardiogram demonstrating unidimensional end-diastolic diameter $\geq$ 6.0 cm). Patients were divided into two groups: group 1 (n = 15), exclusion stitch (Fontan stitch) placed using the beating heart technique; and group 2 (n = 38), exclusion stitch placed with the aorta cross-clamped. Statistical analysis between the two groups was performed using a two-sample Student's t test comparing ischemic times, preoperative and postoperative ejection fraction (EF), morbidity, and mortality. All data were considered statistically significant with p values less than 0.05. Clinical and hemodynamic data were collected from medical records, operative reports, and clinic notes.

Surgical Technique

All patients were monitored for arterial and pulmonary artery pressures intraoperatively and postoperatively. Standard cardiac anesthesia was used. A transesophageal echocardiography (TEE) probe was used to evaluate preoperative and postoperative LV and mitral valve function. Through a median sternotomy the heart is exposed, and after adequate heparinization the patient is placed on cardiopulmonary bypass (CPB). Myocardial protection was achieved with blood cardioplegia administered antegrade and retrograde.

After completing the revascularization or valve repair, the left ventricle is entered. The decision to proceed with the aorta clamped or to remove the aortic clamp and proceed with the beating heart technique was determined intraoperatively by the attending surgeon. The transition between normal myocardium and dysfunctional scar is visualized, or palpated if the clamp is removed. A 2-0 Prolene suture (Ethicon, Somerville, NJ) is placed around the circumference of the scar at the transition zone (usually just at the base of the papillary muscles) and tied down to determine the size of the new ventricular opening. This is commonly referred to as the Fontan stitch. A synthetic or pericardial patch is then secured over the ventricular opening with a running suture. The edges of the ventricular free wall are then approximated using mattress sutures and then reinforced with running 3-0 Prolene (Ethicon). The patient is then weaned from CPB in standard fashion. TEE then confirms contractility and mitral valve function.

Results

All 53 patients had a history of transmural myocardial infarction with a preoperative EF less than 30% determined by either contrast ventriculography, transthoracic, or transesophageal echocardiography. Fifteen patients (group 1) underwent ventricular restoration with the beating heart technique (mean preoperative EF 23.4%). The remaining 38 patients (group 2) were reconstructed with the aorta cross-clamped (mean preoperative EF of 21.4%). The mean age was 63.1 $\pm$ 2.1 for group 1 and 61.9 $\pm$ 4.3 in group 2 (p = 0.86). There were 12 men and 3 women in group 1 versus 31 men and 7 women in group 2. All patients demonstrated a preoperative LV end-diastolic diameter greater than or equal to 6.0 cm and mean preoperative EF for the entire cohort was 22% (8% to 30%). All patients in both groups required concomitant coronary artery bypass (mean 3.5 grafts group 1 vs 2.9 grafts for group 2; p = 0.77). Three patients in group 1 (20%) and 9 patients in group 2 (23.6%) required concomitant mitral valve repair. All but 3 patients (2 patients in group 1 and 1 patient in group 2) were NYHA class III or IV preoperatively.

Total ischemic time, as expected, was significantly longer in group 2 patients 84 $\pm$ 18 minutes versus 60 $\pm$ 15 minutes ($p < 0.05$). Interestingly, however, cardiopulmonary bypass times were not significantly different between groups 109 $\pm$ 24 versus102 $\pm$ 16, p = 0.81. This observation is most likely the result of slightly more bypasses performed in group 1 (3.5) versus group 2 (2.9). Although all patients in both groups were weaned from cardiopulmonary bypass with low to moderated doses of dopamine (3–10 μg), the use of inotropic agents in the postoperative period is highly variable and attending surgeon dependent. Intraaortic balloon pump augmentation was required in 7 patients overall (2 patients in group 1 and 5 patients in group 2) and was removed within 48 hours in all patients.

In analyzing the hemodynamic effects of ventricular restoration between the two groups, we found immediate improvement in the LV function with an increase in the cardiac index from a mean of 2.1 $L \cdot min^{-1} \cdot m^{-2}$ preoperatively to 3.3 $L \cdot min^{-1} \cdot m^{-2}$ postoperatively ($p < 0.01$). This increase in cardiac index was present for the group as a whole (excluding the 7 patients requiring intraaortic balloon pump support) and was not significantly different preoperatively or postoperatively between group 1 and group 2. Figure 1 graphically displays cardiac indices before and 24 hours after ventricular restoration for both groups.

There were no operative mortalities in either group and all patients in both groups were discharged home alive (mean postoperative hospital stay 8.3 days; range 6 to 22 days). All patients had improvement in noninotrope supported LV function with mean postoperative (30 to 60 days following discharge) left ventricular ejection fraction (LVEF) of 36.9% (25% to 52%) in group 1 versus 38.1% (31 to 50%) in group 2, p = 0.079. No patient in either group demonstrated preoperative evidence of ventricular arrhythmia. There was a trend towards postoperative ventricular arrhythmias; however, in the beating heart approach (5/15 vs 9/38) but this did not reach statistical significance (p = 0.42). Although postoperative arrhythmias did not add to the immediate morbidity, 4 of these

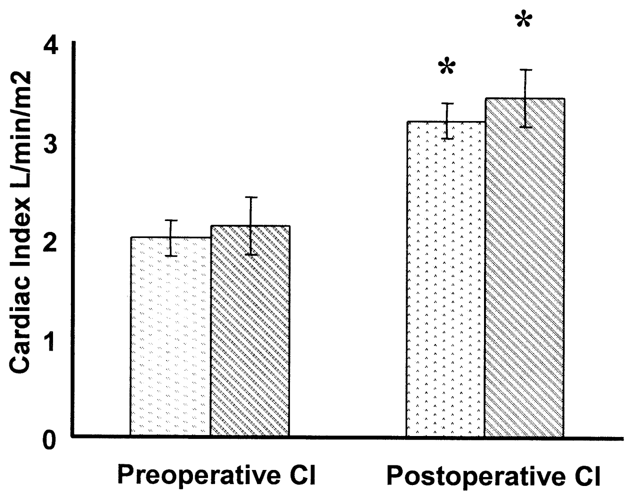

*Fig 1. Preoperative and postoperative cardiac index (*CI*); *p less than 0.01. ▨= beating heart; ▧ = cross clamp.*

patients (all in group 1) eventually required pacing. Two patients in the entire cohort (1 patient in group 1 and 1 patient in group 2) had at least one readmission within 12 months with evidence of heart failure. The group 1 patient went on to successful transplant 11 months later, whereas the group 2 patient died 10 months later. Treating both of these patients as a treatment failure, there was no significant difference in outcome between the two groups ($p = 0.731$; see Table 1).

Comment

There is little doubt that patients with severely depressed LV function secondary to large transmural ventricular scars or dilated cardiomyopathy can exhibit significant improvement with ventricular restoration [6,8–10]. The beating heart technique theoretically allows better determination of the akinetic site for the exclusion stitch placement and for some, is the preferred myocardial protective technique used for ventricular restoration. However, the primary surgical objective in treating dilated cardiomyopathy is restoration of ventricular geometry by exclusion of akinetic muscle and reducing left ventricular size. Removal of the aortic cross-clamp and digital palpation of the beating open heart is conceptually an ideal way to exclude nonviable muscle. The distinct transition zone between normal and pathologic myocytes; however, is often subtle. While digital palpation to determine this distinction may be accomplished by some, it is by no means the only way to determine the best location to place the exclusion stitch. In fact, exclusion stitch placement is much harder in a beating heart particularly if the infarct is recent. We believe the location of the Fontan stitch and subsequent ventricular volume can accurately be determined preoperatively with echocardiography and the use of ventriculograms.

We have adapted a multidisciplinary approach to address predicted LV volume. Left ventricular internal dimensions at end systole and end diastole are obtained primarily from parasternal long-axis echocardiographic views. These dimensions are then cross referenced to left ventriculograms obtained from cardiac catheterization. Akinetic and hypokinetic segments are easily identified and the degree of ventricular reduction required is obtained from these views. Typically, this reduction is in the order of one-quarter to one-third the preoperative ventricular volume.

The beating heart technique was used in only 15 of 53 ventricular reconstructions in this cohort. Although there was an increase in ischemic time in group 2, there was no statistical difference in postoperative LV function, morbidity, or mortality between those patients undergoing ventricular restoration with or without aortic cross-clamping. We strongly think the added ischemic time associated with continuous cross-clamp has no detrimental effects following ventricular restoration. While some may argue the added ischemic time is significant, the benefits provided by continuous cross-clamp are clear. The ability to work in a bloodless and motionless field allows for easier and more precise exclusion suture placement. Some patients with akinetic or dyskinetic ventricular wall segments often have intraventricular thrombus formation [9]. Although no patient in either group clinically demonstrated cerebral emboli, the cerebral protection provided by continuous cross-clamp seems obvious.

Our series demonstrated a significant increase in postoperative cardiac index (2.1 to 3.3 $L \cdot min^{-1} \cdot m^{-2}$, $p = 0.01$) for the entire cohort with no statistical differences between groups 1 and 2. We have drawn no hard conclusions from these 24-hour postoperative indices, as all patients in this cohort were on some degree of inotropic support, which could account for hemodynamic changes. The bottom line is restoration of the elliptical shape of the

Table 1. Operative and Outcome Data of Group 1 and Group 2

	Group 1 (n = 15)	Group 2 (n = 38)
Preoperative LVED volume (cm)	6.8 ± 0.7	6.5 ± 0.4
Preoperative LVID es (cm)	6.0 ± 0.8	5.8 ± 0.6
Postoperative LVED volume (cm)	5.4 ± 0.4	5.3 ± 0.5
Postoperative LIVD es (cm)	4.8 ± 0.8	4.5 ± 0.6
Mean preoperative EF (%)	21.4 ± 6.2	23.4 ± 4
Mean postoperative EF (%)	36.9 ± 4.2	38.1 ± 5.1
Ischemic time (min)	60 ± 15	84 ± 18[a]
CPB time (min)	109 ± 24	102 ± 16
Number of vascular grafts	3.5 ± 0.9	2.9 ± 1.0
Ventricular arrhythmias	5	9
Mean hospital stay (days)	7.9 ± 1.8	8.4 ± 2.9
Operative mortality	0	0
Recurrent heart failure	1	1
Long-term mortality	0	1

[a] $p < 0.05$

Group 1 is beating heart Dor; Group 2 is cross-clamp Dor.

CPB = cardiopulmonary bypass; EF = ejection fraction; LVID es = left internal ventricular diameter (end-systolic); LVED = left ventricular end-diastolic diameter.

ventricle regardless of technique is used results in excellent hospital survival.

The relationship between improvement in LV performance and symptomatic improvement is not clear [9]. Although improvements in LV function after ventricular restoration may not always be profound, some patients still experience symptomatic improvement. Patients requiring only slight improvement in LV function, which may not be detected by current imaging techniques, could explain the observed symptomatic improvement. All but 3 patients in our series were New York Heart Association class III or IV preoperatively with only 5 patients (2 patients in group 1, and 3 patients in group 2) remaining in these classes postoperatively. Follow-up data for the entire cohort is varied depending on the elapsed time since ventricular restoration (6 to 48 months). With the exception of the 2 patients readmitted for heart failure (1 patient in group 1, and 1 patient in group 2) the remaining patients in both groups continue to exhibit freedom from heart failure.

Outcome benefit was not an endpoint of this investigation and no conclusions can be drawn from the data regarding this. The critical nature of patients in this series is one that is commonly seen in large university settings and poses tremendous challenges to the health care team. Our review did not involve a control group of similar patients with critically ill left ventricles who were not managed with ventricular restoration. Further prospective investigation into outcome benefits in this setting is ongoing.

In conclusion, ventricular restoration by the Dor technique clearly improves hemodynamic function and clinical status in patients with severely diseased and dilated left ventricles. We have demonstrated remarkable success with this technique over the past 3 years in patients with ischemic cardiomyopathy requiring concomitant revascularization as well as in patients with moderate to severe mitral reguritation requiring repair [12]. The choice of the beating heart approach or continuous aortic cross-clamp plays little to no role in postoperative outcome of patients undergoing ventricular restoration. Our experience has been the location of the Fontan stitch can be determined preoperatively regardless of which technique is used. Furthermore, the added ischemic time associated with continuous cross-clamp is outweighed by the potential benefits.

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DISCUSSION

DR JOHN V. CONTE, JR (Baltimore, MD): Tom, this is a very nice presentation. I would like to thank you for giving me the manuscript ahead of time, which was also very well written, and you are to be congratulated on that. I would like to thank the Association for the opportunity to discuss this paper. This is an exciting new area for heart failure surgeons, and I think we are going to be seeing more and more of this in the future.

As you mentioned, a lot of this early work has been based on Dr Dor's work, but also one of his trainees, Dr Lorenzo Menicantti from Milan. He has really added a lot to the basic science we understand behind this operation and has stressed the interaction between the volume, the shape, and the proper orientation of the papillary muscles in reconstructing these ventricles. And one of the things that struck me in reviewing the paper and hearing your presentation is how you use preoperative studies to determine the size of the ventricle.

One of the things that has come out in the literature, both in published studies from the RESTORE group as well as in Dr Menicantti's and Dr Dor's early studies, is that it is difficult to determine what volume to reconstruct the ventricle to based on just looking at scar tissue. Doctor Dor uses a simple balloon that he inflates to a volume at about 50 to 75 mL per meter squared body surface area, and Dr Menicantti works with an elliptical-shaped balloon, which is marketed as a mannequin. How do you relate your preoperative studies with determining the exact size ventricle you want to achieve? That is the first question.

The second question really has to do with determination of the ejection fraction in your patients. And the reason I ask that question is I recently operated on a patient whose preoperative ejection fraction (EF) was 20%, postoperatively it was 45%, but this was with inotropes. When I restudied that patient 6 weeks later the ejection fraction was down to about 32%, certainly an improvement, but how much of an improvement I am not really sure.

I do want to comment, though, that the group of patients that you and your colleagues at the University of Virginia operated on was certainly sicker than most of the patients in the literature, and your 0% operative mortality and approximately 15% improvement in ejection fraction is remarkable. You and your colleagues are to be congratulated. Again, nice job, and I appreciate the opportunity to hear your answers.

DR MAXEY: Thank you, Dr Conte, for your comments and questions. To address the preoperative imaging study, as I mentioned, we use transesophageal echo to determine the ideal postprocedure ventricular volumes.

There have been numerous reports, most of which are extensive mathematical derivations of calculating ventricular volumes, and to be quite honest with you we don't use them. We use a multidisciplinary approach with our cardiologist. We look at the echo, then determine to what degree the ventricle must be reduced and where to place our exclusion stitch. Truthfully, the exclusion stitch or Fontan stitch in just about every patient is placed just at the base of the papillary muscles. I am aware of the balloon techniques described by other groups, but we simply have not used them.

As far as postoperative EFs, we are part of a large multi-institutional study looking at ventricular restoration, and these patients are evaluated with echocardiography before being discharged. At that time they are off inotropes and I think we are getting a true reading of left ventricular function.

DR CONTE: Getting back to the first part of the question, do you believe that measured volumes are really important or do you just kind of look at it and go for what you feel to be scar tissue and try to exclude it at that point? As I have done some of these operations, I have measured the dilated ventricular volumes and I have tried to calculate its appropriate size to use for the ventricular reconstruction according to the complex formula that many have used. Sometimes the balloons that I have used based on those calculations haven't worked and they seemed too large or too small. In that situation I have simply done what it seems that you and your colleagues do, and I don't know what the right answer is.

Do you believe that those volume measurements are really not important, that we ought to just go ahead and do the common sense thing? In my experience, it seems the common sense thing actually seems to work most of the time. However, I don't know if we can rely on our gut feelings alone.

DR MAXEY: That is an excellent point. I think simplicity is probably the answer to many problems that we encounter, but, as I had mentioned, we rely on our cardiologist to help us determine what we feel is an adequate postoperative volume. We believe that the size of the ventricle one is left with is more important than trying to exclude scar. We determine prior to incision whether the ventricle needs to be reduced by one-third or one-half and then attempt to achieve that goal.

DR GARY H. DWORKIN (Clearwater, FL): The outcomes here are just superb, but I would like to focus on the 10% or so of patients that were in cardiogenic shock. You imply that these people have had an acute infarct or are in the midst of an acute infarct.

In my own experience with this operation, which has also been quite good, these are a group of patients that have had poor results. I would like you to comment on that because my recollection is that there is a subset of patients in Dr Dor's data in which he does report operating on patients with an acute infarct. Were your patients having an acute anterior infarct or an infarct in a territory away from the anterior wall?

This concept of doing an infarctectomy in the face of a relatively acute infarct, within a week or so, has been disappointing in my hands.

DR MAXEY: That is a very good point. The data on the acute subset of patients I presented was published last year. We specifically reviewed these 6 patients and noted a surprisingly good outcome in these patients. These patients did infact have anterior myocardial infarctions (MI) and were referred with balloon pumps in place for transplant consideration. They all had relatively large akinetic areas of their anterior wall. All of these patients did well, but this is a work in progress.