somewhat stiffer than virgin young material (such as with a bioprosthesis or in older patients[4]).

Assessment of the results of repair by direct visualization is the commonly used technique not imitating diastolic pressure. Without diastolic pressure, the leaflets show unpredictable irregularities in their morphologic appearance, making the assessment difficult (Figure 1, *B* and *C*). The strength of the work of Tsagakis and colleagues[1] is their reintroduction of angioscopy of the aortic valve after repair.[5] This technique nicely shows the morphology of the leaflets, but only from a top view in 2 dimensions. The coaptation line can clearly be seen, but less so the height of the leaflets and the coaptation depth. For assessment of the functional relevance of the abnormalities, adequate diastolic pressure and simultaneous quantification of regurgitation would be helpful. Probably the presented angioscopic visualization will be refined in an attempt to reach a precision that allows decision making. Aside from that, the questions are as follows: What is in general the value of angioscopy, and what is its difference from commonly used direct inspection of the repaired valve? Furthermore, can we improve this direct inspection with special holders imitating diastolic pressure? In the future, probably other techniques such as preoperative 3-dimensional printing of the individual root with the possibility of in vitro preclinical repair attempts or even more sophisticated computational evaluation will provide detailed information on how to repair before we step into the operating room.

After all, long-term results of more than 20 years in these relatively young patients are needed to find the best indications, techniques, and limitations. Prospective, randomized trials would give the most reliable answers, but the complexity of pathologies and the diversity of surgical techniques are considerable obstacles. Meanwhile we must rely on quorum sensing, and every measure to improve the quality of repair is desirable. Angioscopy may become one of those tools.

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Aortic cannulation system for minimally invasive mitral valve surgery

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See related commentary on pages 1672-3.

Port-access technology with an endoaortic clamp (EC) or transthoracic clamp has been widely adopted and confirmed as having excellent clinical outcomes.[1] Nevertheless, concerns still remain about the risks of vascular and neurologic events potentially associated with the use of retrograde aortic perfusion and balloon manipulation, particularly in patients with aortoiliac atheromatous disease.[2,3]

Because of these concerns, a minimally invasive approach is denied to these high-risk patients relegating them to standard sternotomy. This situation prompted the development of a device for direct ascending aortic cannulation and clamping to extend minimally invasive mitral valve surgery (MIMVS) even to patients initially ineligible. The Endodirect (ED) cannula (Edwards Lifesciences, Irvine, Calif) allows antegrade arterial perfusion and insertion of an EC for aortic clamping, cardioplegia delivery, and aortic venting.[4] Potentially, its use can avoid the risk of aortoiliac dissection and of retrograde embolism with neurologic injury related to retrograde aortic perfusion. It also provides a better stability for the EC and a lower risk of balloon migration.

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TABLE 1. Preoperative patient characteristics, operative details, and postoperative outcomes (n = 65)

Age (y, mean ± SD)	68.7 ± 9.5
Female sex (no.)	14 (21.5%)
Body mass index (kg/m^2, mean ± SD)	25.0 ± 3.7
Hypertension (no.)	43 (66.1%)
Diabetes (no.)	4 (6.1%)
Chronic obstructive pulmonary disease (no.)	6 (9.2%)
Atrial fibrillation (no.)	19 (29.2%)
Peripheral vascular disease (no.)	40 (61.6%)
Abdominal aortic aneurism (no.)	6 (9.2%)
Aortoiliac-femoral high tortuosity (no.)	19 (29.2%)
Ischemic MR (no.)	14 (21.5%)
Degenerative MR (no.)	37 (56.9%)
Logistic euroSCORE (mean ± SD)	9.7 ± 13.1
Ejection fraction (%, mean ± SD)	55.9 ± 13.2
PAPs (mm Hg, mean ± SD)	45.9 ± 12.7
Previous cardiac surgery (no.)	17 (26.1%)
MV replacement (no.)	12 (18.5%)
Mitral prosthesis replacement (no.)	5 (7.7%)
MV repair (no.)	48 (73.8%)
Combined procedures* (no.)	7 (10.8%)
Atrial fibrillation cryoablation (no.)	9 (13.8%)
Cardiopulmonary bypass duration (mean ± SD)	114.4 ± 84.5
Aortic clamp time (mean ± SD)	84.5 ± 21.8
Aortic dissection (no.)	0 (0%)
Endoclamp balloon rupture (no.)	1 (1.5%)
Endoclamp balloon rupture migration (no.)	0 (0%)
Conversion to sternotomy (no.)	1 (1.5%)
Ventilation (h, mean ± SD)	17.7 ± 29.7
Intensive care unit stay (d, mean ± SD)	2.2 ± 2.4
Reoperation for bleeding (no.)	3 (4.6%)
Acute renal failure (no.)	3 (4.6%)
Stroke (no.)	0 (0%)
30-d mortality (no.)	1 (1.5%)

SD, Standard deviation; *MR*, mitral regurgitation; *PAPs*, systolic pulmonary artery pressure; *MV*, mitral valve. *Tricuspid valve repair, atrial septal defect closure, or both.

The aim of this study was to analyze retrospectively our results in the subgroup of patients undergoing MIMVS in which ED technique was used.

MATERIALS AND METHODS

Between January 2006 and March 2014, a total of 624 MIMVS procedures were performed at our division. In 65 patients (10.6%), aortic cannulation and clamping were achieved with the ED system (Table 1). Seventeen patients (26.1%) had previously undergone cardiac surgery. All patients were screened for adequate vascular access either by angiography or by angiographic computed tomographic scan.

Indications for ED use included abdominal aortic and peripheral arterial disease, high tortuosity of the aortoiliac-femoral axis, and very small femoral arteries. Absolute contraindications included porcelain aorta and inability to obtain or maintain single-lung ventilation. Relative contraindications included significant dilation of the ascending aorta (>42 mm), severe chest deformity, and severe adhesions in reoperative surgery. The algorithm for cannulation and clamping strategy is summarized in Figure 1.

The study was approved by the institutional review board.

Operative Technique

The ED technique has been previously described.[4,5] The patient is positioned supine with 45° elevated right chest. An anterolateral minithoracotomy through the fourth intercostal space (5-7 cm skin incision) is performed, and a properly designed rib retractor is placed (Figure 2). A thoracoscopic camera is placed just below the incision, a sixth intercostal space port is created for pump suction and carbon dioxide insufflation. An additional 11-mm port is obtained in the first intercostal space, roughly at the midclavicular line, for the aortic cannula insertion. Before heparinization, 2 purse-string sutures closed with two polytetrafluoroethylene pledgets are sutured on the upper right side of the ascending aorta. Extreme care should be used in placing the 2 purse-string sutures strictly intraparietally to avoid transfixing stitches and aortic hematoma, which could evolve into aortic tearing at the time of ligation, because in the majority of the cases the cannulation site is out of the finger control and reach. Venous return is obtained percutaneously with a jugular and femoral cannulation. Aortic cannulation is then obtained with the ED inserted through the previously described port. The peculiarity of this cannula is the presence of a retractile blade on its tip, allowing its safe single-punch introduction (Figure 3). The

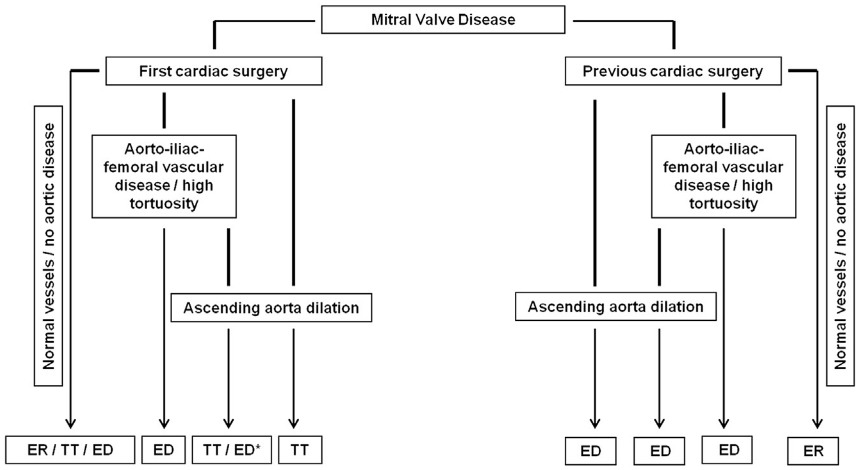

FIGURE 1. Algorithm for cannulation and clamping strategy. *ER*, Endoreturn (peripheral cannulation and endoaortic clamping); *TT*, transthoracic clamping (peripheral cannulation); *ED*, Endodirect (aortic cannulation and endoaortic clamping). *Asterisk* indicates an ascending aorta diameter less than 42 mm.

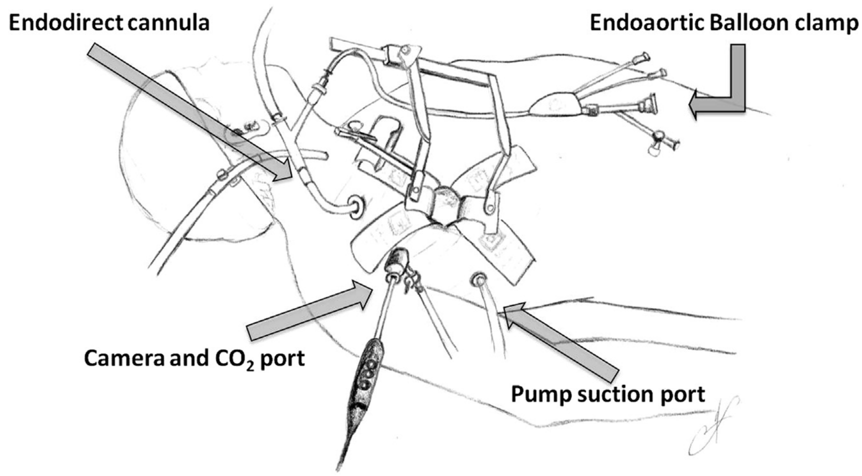

FIGURE 2. Patient's positioning and port and incision placements.

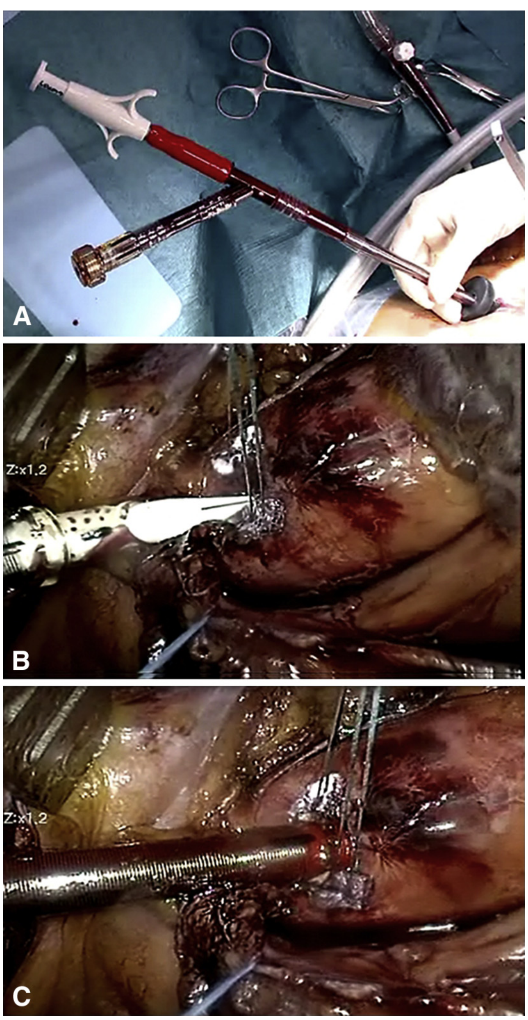

FIGURE 3. Technique of direct aortic cannulation with the Endodirect system. A, Endodirect 24F cannula. B, Two purse-string sutures closed with 2 polytetrafluoroethylene pledgets in the ascending aorta. C, Endodirect cannula in the ascending aorta.

EC is inserted into the aortic cannula, placing the balloon just distal to the tip under transesophageal echo guidance. After cardiopulmonary bypass has been established, the EC can be inflated until the aorta is occluded. A 6-mg dose of adenosine is injected into the root, and cardioplegia is started. After weaning from cardiopulmonary bypass, the arterial cannula is removed by tying the purse-string sutures. This is done before the venous cannula's removal to ensure rapid blood infusion in case of bleeding from the aortic cannulation site by inverting the flow of the cardiopulmonary bypass.

RESULTS

Through this approach, all types of isolated or combined mitral procedures can be performed, as listed in Table 1. Conversion to sternotomy was necessary in 1 case to repair a tear in the ascending aorta in a patient with a previous cardiac surgery in whom the ascending aorta adventitia was completely peeled off during the cannulation phase.

No cases of stroke were recorded. Three patients underwent reoperation for bleeding not related to the aortic cannulation site.

Thirty-day mortality was 1.5% (death unrelated to aortic cannulation).

DISCUSSION

There are 2 usual approaches for MIMVS. In the first, aortic occlusion and cardioplegia delivery are performed through a peripheral EC; in the second, they are performed through a transthoracic clamp and a separate line into the ascending aorta for cardioplegia.

ED cannulation has several advantages relative to the peripherally based approaches. The chief is antegrade flow, which is mandatory in cases of severe peripheral arterial disease to prevent arterial injuries, aortic dissection, and strokes. In our series, none of these complications occurred. The lack of an additional groin incision avoids wound infections and seroma. Moreover, the possibility of performing a single aortic purse-string suture to perform perfusion, clamping, and cardioplegia delivery and air venting is very attractive. In this respect, extreme care should be taken to avoid dissecting the adventitia from the aortic surface in reoperative procedures.

To our knowledge, this is the largest series reporting results on ED technique showing that ED intervention can be performed successfully and safely. ED use can complete the alternative strategies of cannulation and perfusion for MIMVS, avoiding the limitations and the morbidity of a peripheral approach. Despite the fact that the production of this cannula has been suspended for regulatory reasons, our experience underlines that it is definitely a useful and safe tool that allows us to extend MIMVS also to this subgroup of high-risk patients.

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EDITORIAL COMMENTARY

Combining cannula and crossclamp: Not a "Cannulo-Matic," but a versatile technique in the cardiac toolbox

Eugene A. Grossi, MD, and Deane E. Smith, MD

See related article on pages 1669-72.

In their surgical technique article in this issue of the *Journal*, Barbero and colleagues[1] report their institutional experience with an alternative aortic cannulation strategy for minimally invasive mitral valve surgery. The technique uses a specifically designed ascending aortic cannula (EndoDirect; Edwards Lifesciences Corporation, Irvine, Calif) that has a side limb enabling delivery of a balloon-tip catheter. The autoincising cannula obturator has a retractable knife tip that combines the process of puncturing the aortic wall and delivering the cannula through the purse-strings. The catheter paired with this cannula permits proximal endoballoon occlusion of the aorta, either delivery of antegrade cardioplegia or venting, and monitoring of root pressure. This is all accomplished while still allowing distal antegrade aortic flow from the cannula. In summary, this cannula system eliminates the need for external aortic crossclamping and placement of a cardioplegia or vent needle while also decreasing the risk of morbidity from peripheral cannulation in high-risk patients.

Although these features may provide minimal additional benefit for the standard sternotomy approach to the heart, they are very useful for minimally invasive right chest approaches for mitral valve operations. As we have become more sophisticated in identifying those subsets of patients for whom we should not use retrograde perfusion, this may become the go-to technique for the minimitral approach when we desire antegrade perfusion. Barbero and colleagues present their experience and excellent results when routinely applying this technique to these patients.

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