Avoiding vascular complications during minimally invasive, totally endoscopic intracardiac surgery

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Objective: The introduction of minimally invasive valve surgery has been associated with an increased use of peripheral vessel cannulation in cardiopulmonary bypass. These techniques are associated with potential problems at the aorta or cannulation sites. The goal of this study was to review and describe our current practice to avoid vascular problems during cannulation of peripheral vessels.

Method: Data collection for this study was done retrospectively by reviewing the files of all patients who underwent a minimally invasive mitral and/or tricuspid surgery in our institution from 1997 to the end of 2005.

Results: Our cohort of 978 patients revealed an overall rate of peripheral vascular complication of 1.0% with 44.4% presenting at the time of the surgery and 63.6% at long-term follow-up. Acute peripheral vascular problems were treated by simple graft replacement of the diseased segment in most cases. All aortic complications happened at the time of the surgery (complication rate of 0.9%) with 60% of them associated with cannulation problems. Most patients were treated by replacement of the ascending aorta.

Conclusions: A systematic and careful approach is associated with a low risk of vascular problems. Prevention and planning with precise surgical technique remain the main conditions to safely use peripheral cannulation and perfusion for minimally invasive mitral valve surgery.

During recent years, the introduction of minimally invasive valve surgery has been associated with an increased use of peripheral vessel cannulation for cardiopulmonary bypass.¹⁻³ These techniques are associated with potential problems at the cannulation sites, including perforation or rupture of the vessels and intimal tear with retrograde dissection. The goal of this study was to review our current practice to avoid vascular problems during cannulation of peripheral vessels in regular and complicated cases of minimally invasive mitral valve surgery.

Materials and Methods

Data collection for this study was done retrospectively by reviewing the files of all the patients who underwent a minimally invasive mitral and/or tricuspid surgery in our institution. Pre-, peri-, and postoperative findings were noted, and follow-up data were obtained from our institution's database. This retrospective study was approved by the local Ethics Committee, and patient consent was waived because of the anonymous patient data collection and analysis.

History of previous vascular disease or surgery and/or clinical findings suggesting peripheral vascular disease have to be evaluated extensively preoperatively. All patients underwent an evaluation of their iliofemoral arteries before surgery. This was mainly performed at the time of the coronary angiogram by a single injection to visualize the aortoiliac bifurcation and iliofemoral junction. If this cannot be done, we prefer angiographic magnetic resonance imaging (MRI) with 3-D reconstruction of the region.

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Abbreviations and Acronyms

MRI = magnetic resonance imaging

Approach through a right femoral artery and vein cannulation were used for all patients without specific problems. If excessive winding of the right femoral artery (ie, presence of an excessive S-loop of the ileofemoral and aortoiliac junction or an acute angle of the right aortoiliac junction) were found preoperatively (Figure 1), the left femoral artery was used for cannulation to prevent excessive perfusion pressure and decrease the risk of arterial injury during guide wire and cannula placement. Groin vessel cannulation was performed through an oblique incision 1 to 2 cm parallel to the inguinal fold. Two parallel U-stitches with small pledgets on both ends were used on the femoral artery with Goretex 4-0 (W. L. Gore & Associates, Inc, Flagstaff, Ariz). Two regular purse-string sutures were done on the femoral vein. Cannulation was done with a Seldinger technique. For all vessels, proper positioning of the guide wire in the right atrium and in the descending aorta is mandatory to ensure careful placement of the cannulas. Perioperative transesophageal echography allowed us to monitor the position of the guide wire and the position of the femoral cannula in the right atrium. Another option is to use fluoroscopy for complicated cases. This was necessary on extremely rare occasions. Aortic occlusion was done with the use of an intra-aortic balloon in almost every case. A 21- or 23F femoral artery cannula (Cardiovation, Johnson & Johnson, Somerville, NJ), with a side-arm, was used with this technique. We prefer to use the 23F cannula whenever possible to reduce as much as possible the perfusion pressure. Once the cannulas were installed and linked to the cardiopulmonary bypass circuit, perfusion was begun slowly, as careful monitoring of the perfusion pressure is advocated. Usual perfusion pressures are between 200 and 250 mm Hg. Echographic evaluation of the descending aorta was done during the start of the perfusion to look for premature signs of retrograde dissection. The mixture of blood and perfusion fluid may create an image that mimics aortic dissection, which disappears quickly after the mixture is complete.

Specific Cases

Small Femoral/Iliac Arteries

Often in younger women, smaller femoral arteries are found and a 21 Fr cannula cannot be placed safely. To decrease the risk associated with this type of anatomy, a double arterial cannulation was used. In the right femoral artery, a standard 21F arterial cannula with a side-arm was used to introduce the intra-aortic balloon, and on the left side, a standard 17F arterial cannula (DLP, Medtronic, Minneapolis, Minn) was introduced and connected to the cardiopulmonary bypass circuit. Perfusion was started through the left-sided cannula only; the clamp was then removed on the line going to the right-sided cannula to reduce perfusion pressure.

Figure 1. 3-D MRI reconstruction of the iliac arteries allows for better evaluation of the aortoiliac axis on every plane of view. This patient had an unsuspected acute angle of the aortoiliac bifurcation, not visible on simple arteriography.

Stenosis of the Iliac Artery

Evidence of severe iliac disease has to be addressed before or during mitral valve surgery, and, if possible, cannulation is done on the other side of the lesion. If bilateral iliac stenosis is encountered, perioperative dilatation and stenting of the stenosis or an ileofemoral bypass can be performed to safely allow safe placement of the cannula (Figure 2).

Results

A review from our cohort of patients, operated between 1997 until the end of 2005 (978 patients), revealed an overall rate of peripheral vascular complication of 1.0% (10/978) with 44.4% happening at the time of the surgery and 63.6% during long-term follow-up. Table 1 shows the patients' preoperative data and related outcomes according to the type of complication. Table 2 shows the details of the acute and long-term events. Most patients with long-term complications were treated with simple percutaneous angioplasty, with or without associated stenting of the vessel, an average of 14.8 months after their minimally invasive valve surgery. Acute peripheral vascular problems were treated by simple graft replacement of the diseased segment (75%), and 1 patient needed repair of an occluded ileofemoral bypass.

All aortic complications happened at the time of the surgery. Revision of our data revealed an aortic complica-

Figure 2. Preoperative angiogram shows a severe stenosis of the distal left iliac artery and a moderate stenosis of the right iliac artery that is overshadowed by the presence of an intra-aortic balloon pump. Perioperative dilatation and stenting of the left lesion were done to allow safe placement of the arterial cannula. The right side was used to place the occlusive balloon after removal of the intra-aortic balloon. The surgery was performed without complications, but the patient needed a revision of the right femoral cannulation site on postoperative day 1 for acute ischemia of the leg. The patient made an uneventful recovery afterward.

tion rate of 0.9% with 8 aortic dissections and 1 perforation of the aortic wall by the guide wire. Upon review of the files of patients with aortic dissection, 60% (6/9) of these patients

were reported to be associated with cannulation problem due to the small caliber of the femoral artery as reported by the surgeon ($n = 3$), poor quality of the femoral artery ($n = 2$), and difficulty with the insertion of the arterial cannula for unexplained reason ($n = 1$; Table 3). Mortality for aortic complications was 22.2% (2/9). Most patients were treated by replacement of the ascending aorta through sternotomy; only 2 patients had primary repair of the intimal tear, and 1 patient needed an additional venous bypass to the right coronary artery for extension of the tear into the ostium of the right coronary.

Discussion

Few studies have focused on the vascular complication rate associated with peripheral vessel cannulation for minimally invasive cardiac surgery as most of these complications are managed relatively easily with few long-term complications, so the incidence is not really known. Greelish and colleagues have reported an incidence of femoral vessel injury during femoral artery cannulation of 1.4% on a small series of patients.⁴ The incidence of aortic dissection has been reported to be between 0.3% and 3.5% by different groups using different techniques of cannulation and aortic crossclamping.^{1,3,5} Patients who have generalized vascular disease and those who are active smokers are at increased risk of lower extremity vascular complications after heart surgery.⁶ Examination of the preoperative risk factors, although not statistically significant because of the small number of patients in each group, revealed a trend toward an increased incidence of diabetes and smoking history in the different groups of patient with complications, especially in the early and late vascular complication groups. The only preoperative risk factor with a statistically significant association was the history of preoperative peripheral vascular disease in the early and late complication groups. These data reflect the classical combination of vascular disease risk factors leading to an abnor-

TABLE 1. Patient preoperative data and outcomes

	Total	Aortic	Early	Late	P
Patient	978	9 (0.9%)	5 (0.5%)	5 (0.5%)	
Age	62.2 $\pm$ 12.9	64.2 $\pm$ 7.9	61.8 $\pm$ 14.2	63.3 $\pm$ 9.9	NS
Men	537 (54.9%)	5 (55.5%)	3 (60%)	3 (60%)	NS
BSA	1.41 $\pm$ 0.1	1.42 $\pm$ 0.1	1.39 $\pm$ 0.1	1.40 $\pm$ 0.1	NS
HTN	320 (32.7%)	3 (33.3%)	1 (20%)	1 (40%)	NS
Dyslipidemia	293 (30%)	0	2 (40%)	2 (40%)	NS
Smoking	375 (38.3%)	6 (66.6%)	2 (40%)	2 (40%)	NS
Diabetes	50 (5.1%)	1 (11.1%)	1 (20%)	1 (20%)	NS
Vascular disease	8 (0.8%)	0	1 (20%)*	2 (40%)*	<.05*
Renal failure	16 (1.6%)	0	0	0	NS

BSA, Body surface area; HTN, hypertension. * $P < 0.05$ vs total.

TABLE 2. Acute and long-term peripheral vascular events

Acute	Long-term
Iliac artery dissection: 2	Iliac artery stenosis: 3
Iliac artery perforation: 1	Femoral artery stenosis: 1
Thrombosis ileofemoral bypass: 1	Thrombosis ileofemoral bypass: 1
Peripheral ischemia: 1	

mal arterial wall, and the expression of this disease is reflected by the increase incidence of preoperative vascular disease in these groups. The abnormal response of the diseased wall to shear stress and pulse pressure, mainly caused by decreased elasticity of the vessel wall, is probably in part responsible, with the presence of plaques and their mechanical obstruction, for the higher rate of complications seen in these groups.

Our approach to prevent vascular and aortic complications has evolved throughout our experience, starting with stiffer guide wire and relying on fluoroscopy to control the position of the cannulas and the intra-aortic balloon and eventually to a total echographic guidance with softer guide wire. Although the association of peripheral vascular disease and valvular heart disease is not as strong as for coronary artery disease, the primary step in avoiding complication is prevention. We could not demonstrate a difference in the incidence of complications across the course of our experience. By dividing the entire cohort of patients into groups of 100 patients each, there was no statistically significant difference in the incidence of perioperative complications between them (data not shown), suggesting a relatively small effect of the learning curve of this technique. The different modifications in our approach reported earlier have been made mainly at the beginning of our experience and did not reflect on the rate of complications. The introduction of a double femoral cannulation technique is the last modification made and has resulted in no vascular complication in the last 250 patients of this series.

Simple angiographic evaluation of the arteries allows visualization of stenosis or calcifications of the iliac and femoral arteries but is not always adequate to evaluate winding of the artery, which can complicate the cannulation and has the disadvantage of increasing the amount of dye used. One option to obtain better information, if available at the time of the coronary angiogram, is the used of a biplanar angiogram. Otherwise, MRI evaluation with 3-D reconstruction provides complete information on the quality of the arteries along with potential windings of the vessel and the angulation of the aortoiliac junction. This procedure is also painless for the patient and does not require the use of dye.

TABLE 3. Acute aortic complications

Aortic dissection	Aortic perforation
Small femoral artery: 3	Guide-wire placement: 1
Poor quality of the femoral artery: 2	
Cannula insertion: 1	
Balloon positioning: 1	
Unknown: 1	

Mortality = 22.2% (2/9). One myocardial protection problem (stone heart) and 1 multiorgan failure.

The guide wire in the artery must be moved in a slow and careful manner; resistance should never be forced. If resistance is repeatedly encountered, a decision whether to change the side of cannulation must be made. A guide wire can be bent and pushed on a calcified plaque in the artery, creating a small tear of the intima that might go unnoticed until the start of the cardiopulmonary bypass, possibly creating a retrograde aortic dissection. Also, particular attention has to be paid to the curve of the pressure line on the arterial cannula after insertion of the Endoclamp (Cardiovation, Johnson & Johnson). If the curve is very dampened, the Endoclamp catheter might interfere with the flow trough the arterial cannula, creating high perfusion pressure and/or a dangerous jet lesion in the iliac artery. In these cases, a second cannulation in the opposite groin is recommended to introduce the Endoclamp. Other options include the use of an Endo-Direct cannula (Cardiovation) in the ascending aorta, which will be associated with a bigger working port, or the use of a transthoracic clamp.

In the presence of peripheral vascular disease, careful planning is mandatory to safely perform peripheral cannulation. Evidently, the presence of extensive atherosclerotic lesions is a contraindication to the use of peripheral cannulation. Associated vascular procedures during the course of the valve surgery were rarely needed in our series as the association of peripheral vascular disease and valvular heart disease is not as strong as for coronary artery disease. In most cases, cannulation can be performed safely in the right or the left femoral artery. However, if needed, an associated vascular procedure, mainly angioplasty with or without stenting, can be safely performed perioperatively. As stated earlier, the use of the Endo-Direct cannula can be used to obviate complications at the site of the cannulation at the time of removal of the cannula.

Conclusions

In conclusion, a systematic and careful approach is associated with a low risk of vascular problems, even in difficult cases. Prevention and planning with precise surgical technique remain the main conditions to safely use

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peripheral cannulation and perfusion for minimally invasive mitral valve surgery. Since our last modification of the technique, choosing to cannulate both femoral arteries in patients with diseased or small femoral artery, we did more than 250 cases, included in the present study group, without any aortic or vascular complications.

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