

Percutaneous versus open surgical cannulation for minimal invasive cardiac surgery; immediate postprocedural outcome analysis



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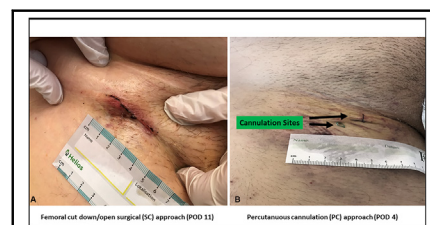
ABSTRACT

Objectives: Open surgical cannulation (SC) is traditionally used for cardiopulmonary bypass cannulation in minimally invasive cardiac surgery (MICS). The percutaneous cannulation (PC) technique using arterial closure devices has also been used in select centers. The aim of this study was to compare outcomes between patients undergoing the PC or SC approach, with a particular focus on cannulation-related groin complications.

Methods: A retrospective analysis of patients undergoing MICS at our institution between January 2018 and April 2022 was performed. Starting from June 2020, 3 surgeons at our institution started using the PC approach. For patients in the PC group, a primary suture-based technique (ProGlide) complemented by a small-sized plug-based closure device (AngioSeal) was used. The primary end point of the study was groin complications following the procedures.

Results: A total of 524 patients underwent MICS through a right lateral minithoracotomy during the study time period. Of these, 88 patients (17%) were cannulated using PC approach and 436 (83%) using SC approach. The total number of cannulation-related groin complications was greater in the SC group (4% vs 0%, $P = .05$). Propensity score matching resulted in 2 comparable groups, with 172 patients in the SC group and 86 patients in the PC group. The number of groin complications remained greater in the SC group ($P = .05$). In-hospital mortality was comparable between groups (1% PC vs 0% SC, $P = .3$).

Conclusions: The PC approach is a safe cannulation technique for patients undergoing MICS. It minimizes postoperative groin complications with no obvious negative impact on outcomes. (JTCVS Techniques 2022;16:28-34)



Result after open surgical versus percutaneous groin cannulation.

CENTRAL MESSAGE

Percutaneous cannulation using arterial closure devices can be safely implemented in minimal invasive cardiac surgery.

PERSPECTIVE

The percutaneous cannulation approach is a safe cannulation technique for patients undergoing minimal invasive cardiac surgery. It minimizes postoperative groin complications with no obvious negative impact on outcomes.

▶ Video clip is available online.

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Read at The American Association for Thoracic Surgery Mitral Conclave Workshop, Boston, Massachusetts, May 13-14, 2022.

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Received for publication May 15, 2022; revisions received July 14, 2022; accepted for publication Aug 12, 2022; available ahead of print Sept 8, 2022.

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2666-2507

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<https://doi.org/10.1016/j.jtc.2022.08.021>

Minimally invasive cardiac surgery (MICS) is routinely used in several centers around the globe with very good outcomes.^{1,2} Most of these surgical techniques include cannulation of the groin for the establishment of cardiopulmonary bypass (CPB), requiring an additional incision for exposure to the femoral vessels. Groin complications, particularly hematoma, access-site infection, and lymphatic fistula, are among the feared complications after SC. Such complications are associated with prolonged hospital lengths of stay post-MICS.

The field of transcatheter aortic valve replacement (TAVR) has made substantial progress over the last 2 decades. This progress was accompanied by the introduction of several arterial closure devices (ACDs) that facilitate safe and uneventful percutaneous approaches for these procedures.³ These ACDs permit the placement of larger sheaths and cannulas percutaneously. A high rate of patient

Abbreviations and Acronyms

ACD	=	arterial closure device
CPB	=	cardiopulmonary bypass
IQR	=	interquartile range
MICS	=	minimally invasive cardiac surgery
PC	=	percutaneous cannulation
SC	=	surgical cannulation
TAVR	=	transcatheter aortic valve replacement

satisfaction is reported after these procedures.⁴ Therefore, many centers, including ours, started implementing these ACDs routinely in patients requiring MICS.⁵ The aim of this study was to compare outcomes between patients undergoing PC or SC approach in MICS, with a particular focus on cannulation-related groin complications.

METHODS

Between January 2018 and April 2022, a total of 524 consecutive patients underwent MICS via a right minithoracotomy at Leipzig Heart Center. Patients requiring transcatheter and/or minimal invasive aortic valve replacement were excluded. Starting from June 2020, 3 surgeons at our institution started using the PC approach for all MICS cases. The primary end point of the study was groin complications following the procedures. All reported complications were analyzed, including bleeding, hematoma, limb ischemia, lymph fistula formation, delayed wound healing, and wound infection.

Data on preoperative and intraoperative parameters as well as early postoperative outcomes were entered prospectively in our hospital electronic medical record system and then analyzed retrospectively. Ethics review board approval was granted by the local ethics committee (study approval #176-12-21052012).

Operative Techniques and ACD Deployment

No routine Doppler examination and/or computed tomography scans are performed before MICS surgery, unless the patient has a history of peripheral vascular disease and/or history of groin complications. A 21- to 27-Fr venous cannula and 16- to 20-Fr arterial cannula were used for cannulation in both groups. The SC group underwent surgical exposure of the groin vessels via a 2- to 4-cm incision, followed by placing a purse string suture and cannulating the vessels under transesophageal echocardiography guidance. At the end of surgery, the cannulae were removed and the purse string sutures were tied. The wound was then closed in the usual manner with a subcutaneous and a subcuticular running suture without the use of a drain (Figure 1, A).

In the PC group, ultrasonic guidance was used according to surgeon preference, but particularly in patients with obesity. Routine use of ultrasound is very helpful and facilitates optimal puncture-site selection in case of arterial calcification. Percutaneous access was achieved by transcatheter needle puncture of the femoral artery and vein, and guidewires are placed under transesophageal echocardiography guidance in the descending aorta and the superior vena cava following heparinization. For arterial cannulation in the PC group, a primary suture-based technique (Perclose ProGlide system; Abbott Vascular) placed before cannulation (Video 1) complemented by a small-sized plug-based closure device (AngioSeal; Terumo) following decannulation was used. The venous cannula was placed using the Seldinger technique with the tip of the cannula extending into the superior vena cava under transesophageal echocardiography guidance. At the end of CPB, a single mattress suture was placed around the

venous line, which was then removed and manual compression was applied.

Only one ProGlide system was used at the time of arterial cannulation, regardless of the cannula size. The device was introduced into the femoral artery using the arterial wire as a guide (see Video 1). The wire was removed and after predilation with the smallest sized dilator, the device was deployed. The arterial cannula was then placed using the rest of dilators (up to 18 Fr) and connected to the arterial line of the CPB. The cannula was left in place and secured until the end of the surgery. Once CPB was weaned and the venous cannula removed, a new guidewire was placed via a needle passed through the wall of the arterial cannula under transesophageal guidance, to confirm that the wire is in the descending/abdominal aorta. The arterial cannula was then removed, leaving the newly introduced guidewire inside the artery and the previously placed ProGlide suture was tightened. The next step was based on the amount of bleeding after tightening of the ProGlide suture over the guidewire. For patients with mild oozing and/or those with 16-Fr arterial cannula, only manual compression and a subcutaneous U-stitch was used. For patients with moderate or more-than-moderate bleeding, the guidewire was used to place a 6-Fr or 8-Fr AngioSeal device. This was followed by subcutaneous U-stitch (Figure 1, B). A pressure bandage was applied, if necessary, for 4 to 6 hours postoperatively.

The decision between 6-Fr versus 8-Fr AngioSeal device is based on the bleeding tendency following ProGlide system application. For patients with moderate bleeding, 6-Fr AngioSeal is appropriate. However, in patients with severe bleeding and/or if this is any issue with the application of the ProGlide system, we prefer 8-Fr AngioSeal device. Notably, we use almost exclusively a 6-Fr AngioSeal device.

Statistical Analysis

Continuous study variables are reported as median with the interquartile range (IQR). For categorical data, the frequencies are given. Statistical tests were performed according to type, normality, and scedasticity of data with Welch 2-sample *t*-test, Wilcoxon signed-rank test, or χ^2 test. Due to differences in the preoperative characteristics of patients undergoing SC or PC, propensity score matching was performed. The following variables were included in the matching based on significant differences in the unmatched groups: diabetes, preoperative heart rhythm and logistic European System for Cardiac Operative Risk Evaluation. For propensity score matching, we used the nearest-neighbor approach without replacement with caliper size of 0.2 and a 2:1 SC:PC ratio (R package MatchIt).

RESULTS

A total of 524 patients (age 60 years [IQR, 52-68 years], 69% male, median body mass index 25 [IQR, 23-28]) underwent MICS through a right lateral minithoracotomy during the study time period. Of these, 88 patients (17%) were cannulated using the PC approach and 436 patients (83%) using the SC approach. The type of surgical procedures included mitral valve surgery in 440 patients (84%), tricuspid valve surgery in 19 patients (4%), combined mitral and tricuspid valve surgery in 48 patients (9%), and tumor resection in 22 patients (4%). The PC approach was successful in all cases except for 1 patient, who was converted from the PC to the SC approach because of closure device failure and subsequent bleeding. Intraoperative cannulation-related retrograde type A dissection occurred in 1 patient from each group (1.1% vs 0.2%, $P = .3$). The in-hospital mortality of the entire cohort was 0.4%.

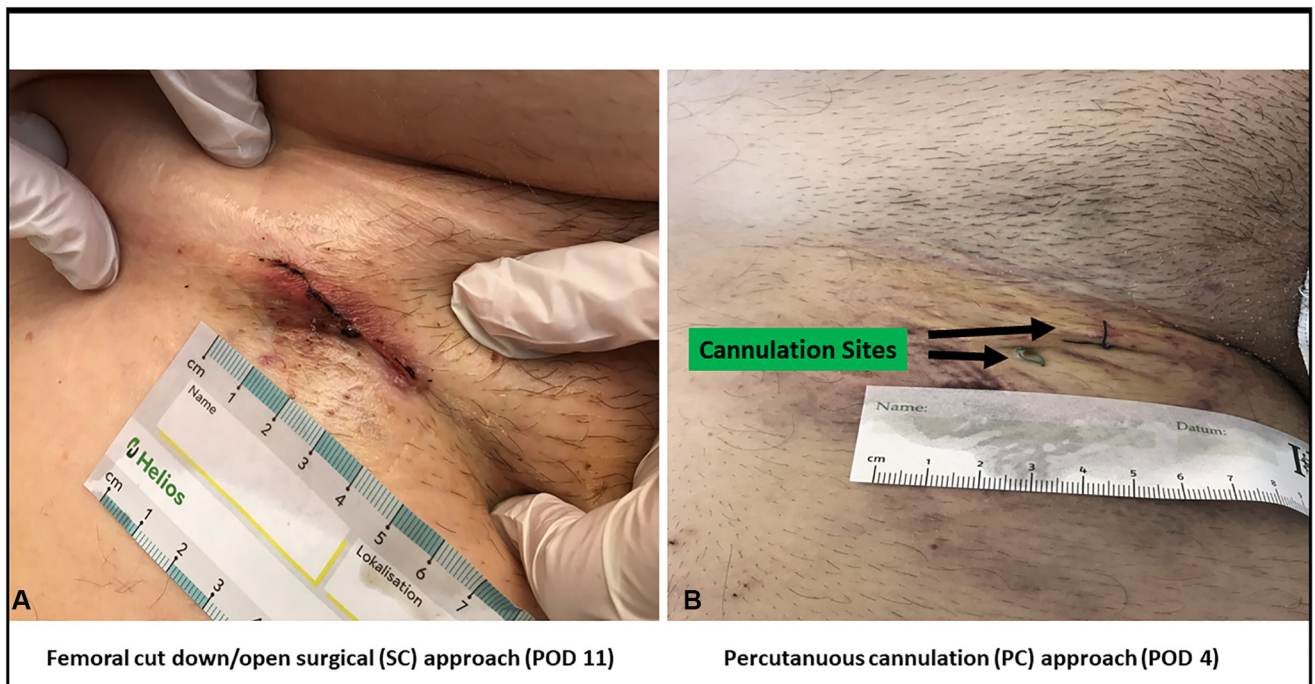


FIGURE 1. A, The result following conventional (SC) cannulation technique. B, The result following the PC cannulation technique. SC, Surgical cannulation; POD, postoperative day; PC, percutaneous cannulation.

Table 1 shows the preoperative patients characteristics in both groups. The incidence of diabetes mellitus and atrial fibrillation was greater in the SC group (39% vs 10% and 23% vs 10%, $P \leq .001$ and $.007$, respectively). Logistic European System for Cardiac Operative Risk Evaluation was also greater in the SC group (0.82 vs 0.52, $P = .001$).

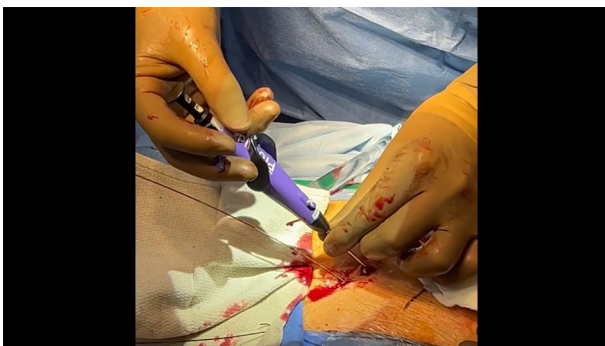
Table 2 shows the early postoperative outcomes in both groups. The rate of groin complications was greater in the SC group (4% vs 0%, $P = .05$). A total of 8 patients (4%) in the SC group required the use of vacuum-assisted

closure therapy for wound infection/dehiscence/lymph fistula formation, whereas none of the patients in the PC group had wound infection and/or required vacuum-assisted closure therapy ($P = .4$). The rate of postcardiotomy extracorporeal membrane oxygenation use and in hospital mortality was comparable between the groups (0.7% vs 1.1%, $P = .05$ and 0.2% vs 1.1%, $P = .3$, respectively). The length of hospital stay for the index hospitalization was also comparable between the groups ($P = .4$).

To create 2 comparable groups and account for the cofounders that may affect the finding, a propensity score analysis was performed and resulted in 2 similar groups of patients (Table 3). A total of 172 patients in the SC group and 86 patients in the PC group remained after matching. No statistically significant differences between the preoperative characteristics remained after matching. Table 4 shows postoperative outcomes in the matched groups. A total of 8 patients (5%) had any form of groin complication in the SC group compared with no groin complications in the PC group ($P = .05$). All of the other parameters including in-hospital mortality were comparable between the groups.

DISCUSSION

This study showed the feasibility of implementing percutaneous closure devices for patients undergoing MICS. The procedure is safe, and the risk of cannulation-related complications was comparable between the groups. The



VIDEO 1. This video shows the PC technique for MICS using a suture-based device (ProGlide). Removal of the cannulas are also shown with the application of an AngioSeal system at the end of the procedure. Video available at: [https://www.jtcvs.org/article/S2666-2507\(22\)00462-X/fulltext](https://www.jtcvs.org/article/S2666-2507(22)00462-X/fulltext).

TABLE 1. Preoperative characteristics of the entire patient population

	Open median (IQR) N (%) n = 436	Percutaneous median (IQR) N (%) n = 88	P value
Preoperative parameters			
Age, y	60 (53, 68)	60 (52, 67)	.7
Female sex	134 (31)	29 (33)	.7
Body mass index, kg/m ²	25 (23, 28)	26 (23, 28)	.9
Systemic hypertension	263 (60)	49 (56)	.5
Diabetes mellitus	170 (39)	9 (10)	<.001
Peripheral vascular disease	8 (1.8)	4 (4.6)	.12
Left ventricular ejection fraction	61 (55, 66)	62 (56, 66)	.7
Previous cardiac surgery	3 (1)	0 (0)	.9
Endocarditis	7 (2)	0 (0)	.6
Atrial fibrillation	101 (23)	9 (10)	.007
Log EuroSCORE	0.82 (0.50, 1.35)	0.52 (0.50, 1.00)	.001
Intraoperative parameters			
Length of surgery, min	188 (157, 218)	175 (158, 200)	.1
CPB time, min	131 (106, 158)	118 (108, 136)	.05
Left atrial myxoma excision	21 (5)	1 (1)	.1
Patent foramen ovale closure	78 (18)	19 (22)	.4
Cryoablation for atrial fibrillation	101 (23)	12 (14)	.05
Left atrial appendage closure	23 (5)	5 (6)	.9
Single-valve surgery			.12
Mitral valve repair	352 (81)	76 (86)	
Mitral valve replacement	9 (2)	3 (3.4)	
Tricuspid valve repair	9 (2)	2 (2)	
Tricuspid valve replacement	5 (1)	2 (2)	
Double-valve surgery			.5
Mitral and tricuspid valve repair	40 (9)	4 (4.5)	
Mitral valve replacement and tricuspid valve repair	2 (0.4)	0 (0)	
Mitral valve repair and tricuspid valve replacement	2 (0.4)	0 (0)	

IQR, Interquartile range; EuroSCORE, European System for Cardiac Operative Risk Evaluation; CPB, cardiopulmonary bypass.

major advantage was the decreased incidence of postoperative groin complications in the PC group compared with the SC group ($P = .05$). No groin complication was documented in the PC group, at least in the immediate postoperative period.

The MICS approach for mitral valve surgery is becoming increasingly popular globally with very good reported outcomes, particularly in high-volume centers.² To limit the thoracotomy incision size, the majority of surgeons perform

TABLE 2. Postoperative outcome of the entire patient population

Postoperative parameters	Open median (IQR) N (%) n = 436	Percutaneous median (IQR) N (%) n = 88	P value
Lymphatic fistula	9 (2.0)	0 (0)	.4
Groin infection	9 (2.0)	0 (0)	.4
Delayed wound healing	6 (1.4)	0 (0)	.6
Hematoma	2 (0.5)	0 (0)	>.9
Femoral arteriovenous fistula	0 (0)	0 (0)	
VAC therapy	8 (2)	0 (0)	.4
Patients with any groin complication	18 (4)	0 (0)	.05
Conversion from percutaneous to open	0 (0)	1 (1.1)	.2
Re-exploration for bleeding	23 (5)	3 (3)	.6
Retrograde type A aortic dissection	1 (0.2)	1 (1.1)	.3
Postcardiotomy ECMO implantation	3 (0.7)	1 (1.1)	.5
Length of hospital stay, d	9 (8)	10 (8)	.4
In hospital mortality	1 (0.2)	1 (1.1)	.3

IQR, Interquartile range; VAC, Vacuum-assisted closure, ECMO, extracorporeal membrane oxygenation.

TABLE 3. Preoperative characteristics of the matched patient population

Parameters	Open median (IQR) N (%) n = 172	Percutaneous median (IQR) N (%) n = 86	P value
Preoperative			
Age, y	57 (49, 65)	60 (52, 67)	.1
Female sex	47 (27)	28 (33)	.4
Body mass index, kg/m ²	25 (23, 28)	25.8 (23, 28)	.4
Systemic hypertension	99 (58)	48 (56)	.8
Diabetes mellitus	18 (10)	9 (10)	>.9
Peripheral vascular disease	3 (2)	3 (3.5)	.4
Left ventricular ejection fraction	62 (55, 67)	62 (56, 65)	.9
Previous cardiac surgery	1 (0.6)	0 (0)	.9
Endocarditis	3 (1.7)	0 (0)	.6
Atrial fibrillation	18 (10)	9 (10)	>.9
Log EuroSCORE	0.66 (0.50, 1.00)	0.52 (0.50, 1.00)	.6
Intraoperative			
Length of surgery, min	186 (152, 214)	175 (158, 199)	.5
CPB time, min	132 (101, 156)	118 (110, 136)	.14
Left atrial myxoma excision	7 (4)	1 (1)	.3
Patent foramen ovale closure	30 (17)	19 (22)	.3
Cryoablation	26 (15)	12 (14)	.8
Left atrial appendage closure	5 (3)	5 (6)	.3
Single-value surgery			.5
Mitral valve repair	149 (87)	76 (88)	
Mitral valve replacement	4 (2)	3 (3.5)	
Tricuspid valve repair	2 (1)	2 (2)	
Tricuspid valve replacement	1 (1)	1 (1)	
Double-value surgery			.8
Mitral and tricuspid valve repair	9 (5)	3 (3.5)	
Mitral valve replacement and tricuspid valve repair	1 (0.6)	0 (0)	
Mitral valve repair and tricuspid valve replacement	0 (0)	0 (0)	

IQR, Interquartile range; EuroSCORE, European System for Cardiac Operative Risk Evaluation; CPB, cardiopulmonary bypass.

peripheral/groin cannulation for CPB. This is usually achieved by performing a groin incision and direct cannulation of the vessels. This procedure is safe and offers the advantage of direct cannulation of the vessels, which may minimize iatrogenic cannulation related complications. However, some patients, particularly patients with obesity, may come back several days after surgery due to complications related to groin cannulation.⁶ One of the feared complications is lymph fistula formation, which may happen due to injury of the lymph vessels at the time of cannulation.⁷ This complication necessitates patients' readmission and may require weeks of wound management. The major advantage of our reported PC technique is the fact that the rate of groin complications was reduced to 0% in the PC group.

The use of ACD increased markedly in the field of the interventional cardiology with the evolution of catheter-based therapies requiring large-bore vascular access, including TAVR, endovascular aortic repair, and mechanical circulatory support.⁸ Arterial access-site closure has shifted from

direct surgical cut-down to percutaneous preclosure using suture-based devices, and has been recently complemented by dedicated large-bore plug-based technologies, such as the collagen-based MANTA device (Teleflex). There are several available ACDs for use. The most frequently used ones at our center include suture-based technique ProGlide as well as plug-based technique (AngioSeal and MANTA). In our recently published CHOICE-CLOSURE (Randomized Comparison of Catheter-based Strategies for Interventional Access Site Closure during Transfemoral Transcatheter Aortic Valve Implantation) trial, a pure plug-based vascular closure technique using the MANTA device during TAVR was associated with a greater rate of access site- or access-related vascular complications, but a shorter time to hemostasis compared with a primary suture-based technique using the ProGlide system.³

Several other centers have started using ACD in MICS to minimize groin complications following the procedure.^{5,9,10} Svenarud and colleagues⁹ describes the technique for ACD using MANTA plug-based ACD only. Similarly,

TABLE 4. Postoperative outcome in the matched patient population

Postoperative parameters	Open median (IQR) N (%) n = 172	Percutaneous median (IQR) N (%) n = 86	P value
Lymph fistula	4 (2)	0 (0)	.9
Groin infection	4 (2)	0 (0)	.4
Delayed wound healing	2 (1)	0 (0)	1.0
Hematoma	0 (0)	0 (0)	.9
Femoral arteriovenous fistula	0 (0)	0 (0)	
VAC therapy	2 (1)	0 (0)	.9
Patients with any groin complications	8 (5)	0 (0)	.05
Conversion from percutaneous to open	0 (0)	1 (1)	.3
Re-exploration for bleeding	9 (5)	3 (4)	.8
Retrograde type A aortic dissection	0 (0)	1 (1)	.3
Postcardiotomy ECMO implantation	1 (0.6)	1 (1)	>.9
Length of hospital stay, d	9 (8, 12)	9 (8, 13)	.2
In-hospital mortality	0 (0)	1 (1.2)	>.9

IQR, Interquartile range; VAC, vacuum-assisted closure; ECMO, extracorporeal membrane oxygenation.

El-Sayed Ahmad and colleagues¹⁰ reported a positive outcome in 268 patients who underwent MICS using the MANTA device without major complications. In that study, the median procedural duration and stays in the intensive care unit were significantly lower in the percutaneous group. Based on the results of the CHOICE-CLOSURE trial, however, we no longer favor the use of this device. Moschovas and colleagues⁵ reported on the outcome of 353 patients who underwent ACD using 2 ProGlide systems and compared the outcome with 92 patients who underwent conventional surgical access. The findings of their study showed that ACD significantly reduces groin complications, operation time, and hospital stay. The advantages of using only the ProGlide system is the fact the guidewire remains in the artery and can be used for additional devices in case of inadequate hemostasis. In the current study, we combined the advantages of the suture-based technique (ProGlide) with a plug-based technique (AngioSeal) with very acceptable results. Needless to say, our study matched the groups to rule out the effect of other factors on the outcome. The main drawback of using AngioSeal is the fact that the arterial guidewire is removed during its deployment, and no additional devices can therefore be deployed. We prefer the combination of ProGlide with AngioSeal based on our extensive experience with this approach in patients undergoing TAVR. In those patients, we perform angiography before and after the procedure. In our experience, the combination of ProGlide with AngioSeal systems provide the best angiographic and hemostatic result.

While the ACD devices offer advantages of minimizing groin complications, care must be taken at the time of device deployment. Percutaneous cannulation of the peripheral vessels may be problematic and require additional wire skills. The use of ultrasound guidance

may lower the risk of femoral vessel injury¹¹ and is therefore recommended for PC. The absence of fluoroscopy at the time of cannulation, in contrast to TAVR procedures, makes PC during MICS surgery more demanding. In the current study, 1 patient in each group developed iatrogenic type A aortic dissection, which may have been related to peripheral cannulation. Another disadvantage of PC is the additional device costs. However, the significant reduction in groin complications and their associated hospital readmission rates and prolonged wound management requirements may compensate for the additional device-related costs.

The PC technique is very efficient in experienced hands and may lead to reduced duration of surgery. The median length of surgery in the unmatched SC group was 188 minutes (IQR, 157-218 minutes) compared with 175 minutes (IQR, 158-200 minutes) in the PC group (Table 1). Although this difference did not reach statistical significance ($P = .12$), this may have been related to the relatively small number of patients in the PC group. The time required to cut the groin and cannulate the vessels and well as the time needed to close the wound are minimized with PC technique. Indeed, Moschovas and colleagues⁵ showed shorter operative times in their comparison of SC and PC techniques.

Limitations of this study include its retrospective nature and the inherent limitations thereof. The patients were identified based on the procedures performed and were not prospectively enrolled. Nevertheless, the surgical reports and discharge letters of all of these patients were reviewed to ensure the accuracy of the recorded variables. Further, no postoperative imaging was performed to rule out arteriovenous fistula formation and/or arterial stenosis caused by ACD. However, decision regarding

next steps/investigations was made based on the clinical finding of the patients. As none of the patients developed signs of limb ischemia postoperatively, no angiography and/or Doppler tests were performed. Needless to say, long-term follow-up of the patients with regard to signs of limb ischemia is missing and is another limitation of this manuscript.

CONCLUSIONS

In conclusion, the PC approach is a safe cannulation technique for patients undergoing MICS. It minimizes postoperative groin complications with no obvious negative impact on outcomes. Further prospective studies may be necessary to confirm this finding.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: less-invasive surgery, groin complications, mitral surgery, percutaneous cannulation