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Comparison of vascular closure devices for access site closure after transfemoral aortic valve implantation

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Background The majority of transcatheter aortic valve implantation (TAVI) procedures are currently performed by percutaneous transfemoral approach. The potential contribution of the type of vascular closure device to the incidence of vascular complications is not clear.

Aim To compare the efficacy of a Prostar XL- vs. Perclose ProGlide-based vascular closure strategy.

Methods The ClOsure device iN TRansfemoral aOrtic vaLve implantation (CONTROL) multi-center study included 3138 consecutive percutaneous transfemoral TAVI patients, categorized according to vascular closure strategy: Prostar XL- (Prostar group) vs. Perclose ProGlide-based vascular closure strategy (ProGlide group). Propensity-score matching was used to assemble a cohort of patients with similar baseline characteristics.

Results Propensity matching identified 944 well-matched patients (472 patient pairs). Composite primary end point of major vascular complications or in-hospital mortality occurred more frequently in Prostar group when compared with ProGlide group (9.5 vs. 5.1%, $P = 0.016$), and was driven by higher rates of major vascular complication (7.4 vs. 1.9%, $P < 0.001$) in the Prostar group. However, in-hospital mortality was similar between groups (4.9 vs. 3.5%, $P = 0.2$). Femoral artery stenosis occurred less frequently in the Prostar group (3.4 vs. 0.5%, $P = 0.004$), but overall, Prostar use was associated with higher rates of major bleeding (16.7 vs. 3.2%, $P < 0.001$), acute kidney injury (17.6 vs. 4.4%, $P < 0.001$) and with longer hospital stay (median 6 vs. 5 days, $P = 0.007$).

Conclusions Prostar XL-based vascular closure in transfemoral TAVI procedures is associated with higher major vascular complication rates when compared with ProGlide; however, in-hospital mortality is similar with both devices.

Keywords Aortic stenosis • Transcatheter aortic valve replacement • Vascular closure device • Vascular complication

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Background

Transfemoral approach for transcatheter aortic valve implantation (TAVI) is associated with superior outcomes when compared with alternative access.[1–3] Thus, the vast majority of TAVI procedures are currently performed via the transfemoral route[3–5] in which haemostasis of the large calibre arteriotomy site is achieved percutaneously by a vascular closure device (VCD). The most common VCDs currently utilized are the Prostar XL percutaneous vascular surgical system and Perclose ProGlide suture-mediated closure system (Both by Abbott Vascular, Abbott Park, IL, USA).[6–8]

Even with decreasing profile of transcatheter valve delivery systems, vascular complication pose a major concern as they are associated with bleeding events, transfusions, acute kidney injury, and increased mortality.[9] Various anatomic and operator-dependent factors have been identified to be associated with vascular complications.[10–14] However, the potential contribution of the type of VCD to the incidence of vascular complications has not been comprehensively studied and selection of either one of the VCD is based on operator preference and is not guided by evidence.

The ClOsure devices iN TRansfemoral aOrtic vaLve implantation (CONTROL) multi-center study was established to compare the efficacy of a Prostar XL-based vascular closure strategy vs. a Perclose ProGlide-based vascular closure strategy.

Methods

The CONTROL multi-center study included consecutive TAVI patients from high-volume TAVI centres. A total of nine centres from Europe, North America, and the Middle East contributed data (see Supplementary material online, *Table S1*). Patients undergoing TAVI with an intention of complete percutaneous transfemoral approach using either the Prostar XL percutaneous vascular surgical system (Prostar group) or Perclose ProGlide suture-mediated closure system (Proglide group) were retrospectively included in the present study. Selection of VCD and number of devices used per patient were at the discretion of the treating physician. Data were collected for cases performed between March 2007 and December 2014 using a dedicated case report form and included baseline characteristics, vascular anatomic data, procedural data including sheath type and size, closure device used, and procedural outcomes with emphasis on vascular complications. All inconsistencies were resolved directly with local investigators and on-site data monitoring. All patients gave written informed consent to a transcatheter aortic valve procedure. The inclusion of patients was approved in each center by a local ethics committee.

Vessel characterization and definitions

The minimal lumen diameter of the ipsilateral iliofemoral arteries of the large vascular access side were measured by multi-slice computed tomography. Vessel tortuosity and calcifications were evaluated as previously described.[14,15] Tortuosity was graded as no tortuosity, mild (30°–60°), moderate (60°–90°), and severe (>90°). Arterial calcification was evaluated by fluoroscopy or by multi-slice computed tomography and was graded as no calcification, mild (<90° of total circumferential arc), moderate (90–180° of total circumferential arc), marked (180–270° of total circumferential arc), and severe calcification (>270° of total circumferential arc). The sheath to femoral artery ratio (SFAR) defines the ratio between the sheath outer diameter and the femoral artery minimal luminal diameter[11] and was calculated for all patients. Major clinical end points were assessed according to the updated Valve Academic Research Consortium criteria.[16] Special emphasis was given for collection of ipsilateral vascular complications such as rupture, dissection, perforation, access site hematoma (>5 cm) and pseudoaneurysm formation. Vascular interventions were documented as well, and included balloon angioplasty, stenting, and need for unplanned surgical intervention.

The primary end point was defined as the composite of major vascular complications or in-hospital mortality. Secondary end points were in-hospital mortality, minor and major vascular complications, need for urgent vascular surgery and minor, major or life threatening bleeding.

Statistical analysis

All data were processed using the Statistical Package for Social Sciences, version 22 (SPSS, Chicago, IL, USA). Categorical variables were reported as frequencies and percentages, and continuous variables as means and standard deviations or medians and interquartile ranges (IQRs). Odds ratios (ORs) were reported as absolute values and 95% confidence intervals (95% CIs). Patients were categorized according to the strategy selected by the operator into either Prostar group or ProGlide group. Continuous variables were compared using the Student's unpaired *t*-test or Mann–Whitney *U*-test, as appropriate. Categorical variables were compared using the χ^2 test; the Fisher's exact test was used if the expected frequency was <5. Univariate logistic regression has been used to identify univariate predictors of vascular complications and bleeding from the major baseline and procedural characteristics; all the variables with a univariate *P*-value of <0.15 have been subsequently tested in a multiple logistic regression models to identify independent predictors of events. Proportionality of hazards was checked and respected. Results of the logistic regression are reported as OR, together with 95% CI.

Given the differences in the baseline characteristics between patients in the two groups (*Table 1*), propensity-score matching was applied to identify a cohort of patients with similar baseline characteristics. The propensity score is a conditional probability of having a particular exposure (Prostar or ProGlide) given a set of baseline measured covariates.[17] The propensity score has been developed using a logistic regression model according to a non-parsimonious approach. Clinical, angiographic, and procedural variables (as listed in *Tables 1* and *2*) were included in the analysis. Pairs of Prostar and ProGlide patients having the same probability score (nearest neighbour method; calliper = 0.25 × SD (logitPs)) have been matched with a 1:1 ratio. Absolute standardized differences among baseline variables, before and after matching, are presented as Love plot. After matching, continuous variables following a normal distribution were compared using the paired sample *t*-test; otherwise, the Wilcoxon rank-sum test was used. Differences for matched categorical variables were analysed with the McNemar's test.

A two-sided *P*-value of <0.05 was considered to be of statistical significance.

Results

A total of 3138 patients were included in the CONTROL study (*Figure 1*), of whom 1556 patients were in the Prostar group and 1582 patients in the ProGlide group. Prior to propensity-score matching, significant differences in the demographics and comorbidities of patients were documented (*Table 1*). Performing propensity-score matching based on baseline characteristics, anatomic and procedural data, resulted in 472 Prostar patients that were matched with 472 ProGlide patients (*Figure 1*). After propensity-score

matching, both groups were well matched, with no significant differences in baseline characteristics (*Table 1*). Minimal luminal diameters, tortuosity, and calcification severity of the common femoral and external iliac arteries were comparable following the propensity matching. *Figure 2* shows a Love plot for absolute differences in baseline covariates before and after matching; a jitter plot showing propensity-score distribution is also presented.

Procedural characteristics of both groups are detailed in *Table 2*. Vascular access was obtained by the Edwards eSheath (Edwards Lifesciences, Irvine, CA, USA) in 47 vs. 43% ($P = 0.3$) of patients in Prostar and ProGlide groups, respectively. The Check-Flo Performer (Cook Medical, Bloomington, IN, USA) was used in 39% of patients in both groups ($P = 1.0$). The complete breakdown of the sheaths used is reported in *Table 2*. Median sheath size was 18-Fr in both groups (IQR 18–18 in both) and an expandable sheath was used in 53 and 48% ($P = 0.15$) of patients in Prostar and ProGlide groups, respectively. Importantly, both the non-expanded and the expanded SFAR were comparable between the two groups. Self-expandable, balloon expandable, and the majority of valves typologies had a similar distribution among patients in the Prostar and ProGlide groups (*Table 2*).

Outcomes

Clinical outcomes are presented in *Table 3*. Incidence of the composite primary end point of major vascular complications or in-hospital mortality (9.5 vs. 5.1%, OR 1.97, 95% CI 1.80–3.29; $P = 0.016$) and major vascular complications (7.4 vs. 1.9%, OR 4.25, 95% CI 1.97–9.18; $P < 0.001$) were higher among the Prostar group. However, in-hospital mortality was comparable between the two groups (2.5 vs. 3.4%, respectively, OR 1.33, 95% CI 0.63–2.82; $P = 0.571$).

The breakdown of specific vascular complications and interventions are detailed in *Table 4*. Vascular complication rates were mostly driven by femoral artery injuries, while iliac and aortic injuries were extremely rare. Femoral haematomas, expression of failed haemostasis, were more frequently observed in the Prostar group (9.5 vs. 1.9%, $P = 0.002$). Femoral artery stenosis occurred more frequently in the ProGlide group (3.4 vs. 0.5%, $P = 0.004$). Other vascular injuries including arterial dissections and aneurysm formation were comparable between the groups. Rates of femoral artery balloon angioplasty (4.2 vs. 1.5%, $P = 0.015$) were significantly higher in the Prostar group when compared with ProGlide group. There was a trend towards higher rates of urgent vascular surgery in the Prostar group (2.8 vs. 1.1%, $P = 0.077$).

Major bleeding (16.7 vs. 3.2%, $P < 0.001$) occurred more frequently in Prostar group when compared with ProGlide group (OR of 6.33; 95% CI 3.45–11.64). Minor bleedings were more frequently observed in the ProGlide group (13.6 vs. 8.9%, $P = 0.032$; OR 1.59, 95% CI 1.06–2.41) (*Table 3*). Other periprocedural complications were comparable between groups including myocardial infarction and stroke. However, acute kidney injury occurred more frequent among Prostar patients (17.6 vs. 4.4%, $P < 0.001$, OR 4.65, 95% CI 2.75–7.85). Use of Prostar was associated with longer hospitalization: median (IQR) of 6 (3–9) vs. 5 (1–9) days ($P = 0.007$). Mortality rates at 30 days were comparable between the two groups (*Table 3*).

No significant interactions were observed between treatment and any of 10 sub-groups with respect to major vascular complications (*Figure 3*). ProGlide use was consistently associated with lower major vascular complications in all sub-groups.

Univariate and multivariable analysis for the identification of predictors of vascular complications and bleeding are presented in Supplementary material online, *Tables S2* and *S3* and Appendix. Patient gender and Prostar use were the only parameters independently associated with both vascular complications and bleeding (see Supplementary material online, *Table S3*). Additionally, patient age and non-expanded SFAR were associated with vascular complications, while BMI, vessel minimal diameters, expanded SFAR, and significant tortuosity were associate with bleeding events.

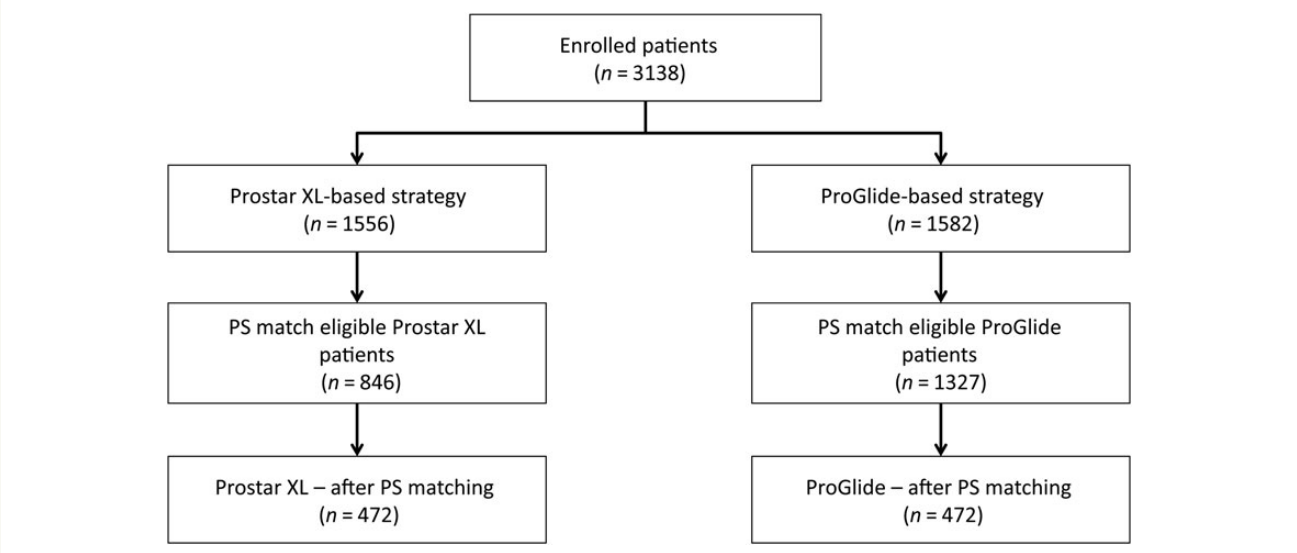

Figure 1 Study population. PS, propensity score.

Table 1 Baseline characteristics before and after propensity-score matching

	Before matching		*P*-value	After matching		*P*-value
	Prostar XL, *n* = 1556	Perclose ProGlide, *n* = 1582		Prostar XL, *n* = 472	Perclose ProGlide, *n* = 472	
Age (years)			0.05			0.31
Mean ± SD	80.7 ± 7.5	82.7 ± 7.7		81.6 ± 6.0	81.5 ± 8.7	
Median (IQR)	82(74–90)	84 (75–93)		83 (75–91)	83 (72–94)	
BMI (kg/m^2)			0.43			0.88
Mean ± SD	26.4 ± 4.6	26.3 ± 5.1		26.3 ± 4.6	26.6 ± 5.5	
Median (IQR)	26 (20–32)	26 (20–32)		26 (20–32)	26 (20–32)	
Female gender	799 (51%)	713 (45%)	<0.001	230 (49%)	231 (49%)	1.00
Diabetes mellitus	406 (28%)	461 (30%)	0.14	138 (29%)	144 (31%)	0.76
Coronary artery disease	652 (42%)	887 (59%)	<0.001	227 (48%)	233 (49%)	0.74
Hypertension	1147 (77%)	1281 (82%)	<0.001	378 (80%)	375 (79%)	0.87
Prior stroke	206 (13%)	237 (15%)	0.09	70 (15%)	69 (15%)	1.00
Prior CABG	239 (15%)	305 (19%)	0.003	75 (16%)	72 (15%)	0.86
Peripheral vascular disease	215 (14%)	308 (20%)	<0.001	77 (16%)	83 (18%)	0.68
Renal failure*	795 (53%)	985 (64%)	<0.001	282 (60%)	283 (60%)	1.00
Dialysis	35 (2.3%)	45 (2.9%)	0.33	13 (2.8%)	13 (2.8%)	1.00
STS score (%)			0.002			0.06
Mean ± SD	7.4 ± 5.5	8.4 ± 5.8		8.3 ± 6.1	8.8 ± 6.3	
Echocardiographic parameters						
Ejection fraction (%)			0.005			0.84
Mean ± SD	52.0 ± 12.6	55.2 ± 13.7		53.3 ± 12.5	53.1 ± 14.7	
Median (IQR)	56 (41–71)	60 (42–78)		58 (43–73)	58 (36–80)	
Mean aortic valve gradient (mmHg)			0.005			0.88
Mean ± SD	49.3 ± 16.9	45.5 ± 15.7		47.6 ± 14.7	48.1 ± 17.3	
Median (IQR)	48 (27–69)	44 (25–63)		47 (27–67)	46 (27–65)	
Aortic valve area (cm^2)			0.05			0.67
Mean ± SD	0.7 ± 0.2	0.7 ± 0.2		0.7 ± 0.2	0.7 ± 0.2	
Median (IQR)	0.7 (0.5–0.9)	0.7 (0.5–0.9)		0.7 (0.5–0.9)	0.7 (0.4–1.0)	
Anatomic data						
Minimal luminal diameters						
Common femoral (mm)			<0.001			0.28
Mean ± SD	7.2 ± 1.2	7.7 ± 1.3		7.4 ± 1.2	7.4 ± 1.2	
Median (IQR)	7.0 (5.4–8.6)	7.6 (5.9–9.3)		7.3 (5.7–8.9)	7.2 (5.8–8.6)	
External iliac (mm)			0.02			0.31
Mean ± SD	7.8 ± 1.6	8.2 ± 1.7		8.0 ± 1.8	8.1 ± 1.8	
Median (IQR)	7.8 (5.9–9.7)	8.0 (6.0–10.0)		7.9 (5.8–10)	8.0 (6.0–10)	
Common iliac (mm)			<0.001			0.62
Mean ± SD	8.7 ± 1.7	8.6 ± 1.8		8.6 ± 1.8	8.6 ± 1.7	
Median (IQR)	8.5 (6.7–10.3)	8.4 (6.0–10.8)		8.4 (6.6–10.2)	8.2 (5.5–10.9	
Calcification ≥ moderate	492 (39%)	429 (28%)	<0.001	180 (38%)	186 (39%)	0.73
Tortuosity ≥ moderate	443 (35%)	572 (38%)	0.18	192 (41%)	195 (41%)	0.90

*Defined as GFR<60 mL/min/1.73 m^2.
BMI, body mass index; CABG, coronary artery bypass graft; IQR, interquartile range; SD, standard deviation.

Learning curve

Analysis of the entire, unmatched cohort according to center experience with a specific vascular closure strategy (first sequential 20 cases vs. >21 cases) indicated that with ProGlide use, there is a learning curve effect with a significant decrease in major vascular complications when comparing the first sequential 20 cases vs. the

Table 2 Procedural variables

	Before matching		P-value	After matching		P-value
	Prostar XL, n = 1556	Perclose ProGlide, n = 1582		Prostar XL, n = 472	Perclose ProGlide, n = 472	
Sheath characteristics						
Sheath size (Fr)			<0.001			0.16
Mean ± SD	18.1 ± 1.5	18.5 ± 2.0		18.2 ± 1.7	18.3 ± 1.7	
Median (IQR)	18 (18–18)	18 (18–18)		18 (18–18)	18 (18–18)	
Non-expanded outer diameter (mm)			0.12			0.12
Mean ± SD	7.3 ± 0.5	7.4 ± 0.7		7.3 ± 0.6	7.3 ± 0.6	
Median (IQR)	7.3 (7.2–7.4)	7.3 (7.2–7.4)		7.3 (7.2–7.4)	7.3 (7.2–7.4)	
Expanded outer diameter (mm)			<0.001			0.36
Mean ± SD	8.0 ± 0.8	8.4 ± 1.0		8.2 ± 0.9	8.2 ± 0.9	
Median (IQR)	7.3 (5.7–8.9)	8.9 (7.3–10.5)		8.9 (7.3–10.5)	8.4 (6.8–10)	
Non-expanded sheath SFAR[a], n			<0.001			0.47
Mean ± SD	1.03 ± 0.2	0.99 ± 0.2		1.01 ± 0.18	1.02 ± 0.20	
Median (IQR)	0.99 (0.8–1.2)	0.98 (0.8–1.2)		1.00 (0.78–1.22)	1.00 (0.81–1.19)	
Expanded sheath SFAR[a], n			0.32			0.32
Mean ± SD	1.14 ± 0.22	1.13 ± 0.23		1.15 ± 0.24	1.14 ± 0.26	
Median (IQR)	1.1 (0.8–1.4)	1.1 (0.8–1.4)		1.1 (0.8–1.4)	1.1 (0.7–1.5)	
Non-expanded SFAR >1.05	587 (39.1%)	468 (29.8%)	<0.001	170 (36%)	153 (32%)	0.27
Sheath type						
Edwards eSheath (Edwards Lifesciences)	606 (39%)	861 (54%)	<0.001	221 (46.8%)	205 (43.4%)	0.30
Check-Flo Performer (Cook Medical)	794 (51%)	468 (30%)	<0.001	185 (39.2%)	185 (39.2%)	1.00
Edwards (non-expandable) (Edwards Lifesciences)	88 (5.7%)	173 (11%)	<0.001	35 (7.4%)	38 (8.1%)	0.72
DrySeal (Gore)	0 (0)	34 (2.1%)	<0.001	0 (0.0%)	19 (4.0%)	<0.001
SoloPath (Terumo)	21 (1.4%)	9 (0.6%)	0.02	11 (2.3%)	5 (2.3%)	0.13
Direct flow (Direct Flow Medical)	33 (2.1%)	18 (1.1%)	0.03	20 (4.2%)	9 (1.9%)	0.058
Ultimum (St Jude Medical)	0 (0)	3 (0.2%)	0.13	0 (0.0%)	1 (0.2%)	0.50
Lotus introducer (Boston Scientific)	7 (0.5%)	17 (1.1%)	0.05	0 0.0%)	10 (2.1%)	0.02
THV type						
SAPIEN	88 (5.7%)	173 (10.9%)	<0.001	35 (7.4%)	38 (8.1%)	0.72
SAPIEN XT	592 (38%)	811 (51%)	<0.001	221 (46.8%)	203 (43.0%)	0.24
SAPIEN 3	14 (0.9%)	50 (3.2%)	<0.001	–	–	–
CoreValve	806 (52%)	497 (31%)	<0.001	193 (40.9%)	204 (43.2%)	0.468
Portico	0	15 (0.9%)	<0.001	0 (0.0%)	5 (1.1%)	0.05
Lotus	7 (0.5%)	20 (1.3%)	0.014	0 (0.0%)	11 (2.3%)	0.01
Direct Flow	33 (2.1%)	18 (1.1%)	0.028	20 (4.2%)	9 (1.9%)	0.04
Symetis acurate	9 (0.6%)	0 (0.0)	0.002	0 (0.0%)	2 (0.4%)	0.25
Bailout THV-in-THV	53 (3.4%)	59 (3.7%)	0.62	10 (1.1%)	21 (2.2%)	0.054

SFAR, sheath-to-femoral artery ration; THV, transcatheter heart valve; IQR, interquartile range; SD, standard deviation.
[a]For non-expandable sheath types, outer diameter value used for expanded and non-expanded SFAR calculation was the same.

>20 cases (82.3%, $P < 0.01$). Conversely, among Prostar cases the rates of major vascular complications remained unchanged (7.5 vs. 8%, $P = 0.84$) (*Figure 4*).

Discussion

The present study represents the first comprehensive, large-scale performance analysis of percutaneous VCD used for arterial access haemostasis in transfemoral TAVI. The main findings of the present study indicate that among a wide range of TAVI centres and operators and in a well-matched TAVI patient population, the composite primary end point of major vascular complications or in-hospital mortality occurred more frequently in patients treated by Prostar when compared with ProGlide. This end point was mainly driven by higher rates of major vascular complications among Prostar patients which did not translate into in-hospital mortality difference.

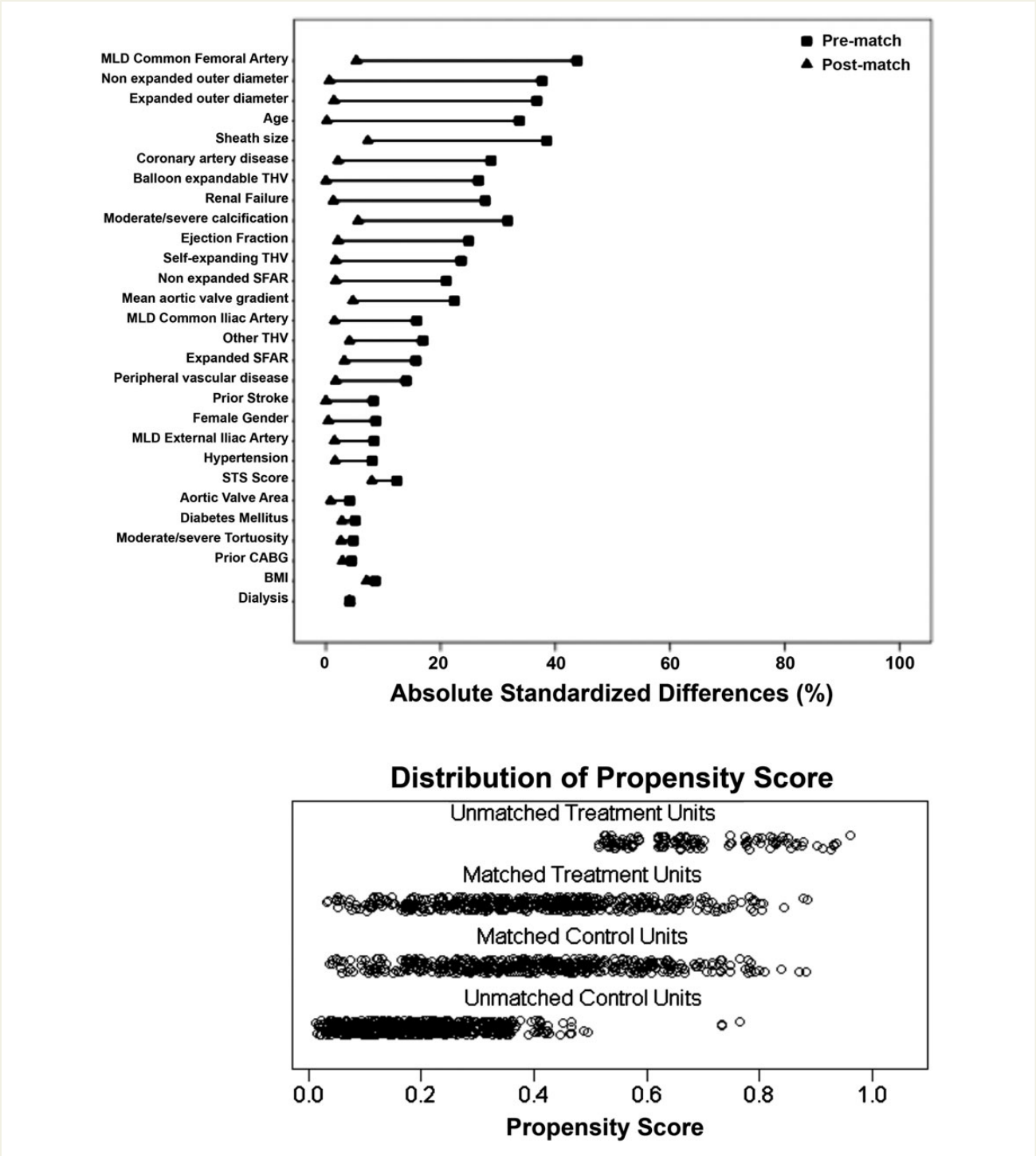

Figure 2 Love and Jitter plot in propensity-matched analysis.

Of note, ProGlide patients experienced higher rates of femoral artery stenosis. However, overall, the ProGlide group demonstrated superior safety profile with significantly lower rates of acute kidney injury and major bleeds, and was also associated with shorter hospital stay when compared with the Prostar group.

Prior data regarding the performance of VCD are derived from percutaneous endovascular aortic procedures. A systematic literature review of percutaneous endovascular procedures indicated that the Prostar XL is as good as surgical closure of the access site in terms of vascular complications.[18] Data regarding performance of VCD in TAVI patients are inconsistent, with Prostar XL failure rates ranging from 7.8 to 33%[12,19–21] and 6.1% with Perclose ProGlide.[6] Two small studies performed head-to-head comparison between Prostar and ProGlide devices. The percutaneous

Table 3 Procedural complications

	Prostar XL, *n* = 472	Perclose ProGlide, *n* = 472	*P*-value	OR (95% CI)
Major vascular complications or in-hospital mortality	45 (9.5%)	24 (5.1%)	0.016	1.97 (1.80–3.29)
Vascular complications				
Any	105 (22.2%)	94 (19.9%)	0.419	1.16 (0.84–1.59)
Major	35 (7.4%)	9 (1.9%)	<0.001	4.25 (1.97–9.18)
Minor	70 (14.8%)	85 (18.0%)	0.203	1.28 (0.90–1.84)
Bleeding				
Life threatening	22 (4.7%)	12 (2.5%)	0.123	1.83 (0.91–3.70)
Major	79 (16.7%)	15 (3.2%)	<0.001	6.33 (3.45–11.64)
Minor	42 (8.9%)	64 (13.6%)	0.032	1.59 (1.06–2.41)
Acute kidney injury				
Any	83 (17.6%)	21 (4.4%)	<0.001	4.65 (2.75–7.85)
Stage 1	54 (11.4%)	5 (1.1%)	<0.001	13.25 (4.80–36.61)
Stage 2	7 (1.5%)	8 (1.7%)	1.000	1.14 (0.41–3.15)
Stage 3	22 (4.7%)	8 (1.7%)	0.014	2.63 (1.16–5.93)
Myocardial infarction	2 (0.4%)	4 (0.8%)	0.687	2.00 (0.37–10.92)
Any stroke	11 (2.3%)	10 (2.1%)	1.000	1.1 (0.47–2.59)
Length of stay			0.007	
Mean ± SD	7.8 ± 7.6	6.5 ± 7.5		
Median (IQR)	6 (3–9)	5 (1–9)		
All-cause mortality				
In-hospital	12 (2.5%)	16 (3.4%)	0.571	1.33 (0.63–2.82)
30-day	20 (4.2%)	25 (5.3%)	0.551	1.25 (0.69–2.25)

IQR, interquartile range; SD, standard deviation.

Table 4 Vascular complications and interventions

	Prostar XL, *n* = 472	Perclose ProGlide, *n* = 472	*P*-value
Femoral artery			0.002
Rupture	9 (1.9%)	5 (1.1%)	0.424
Dissection	12 (2.5%)	14 (3.0%)	0.845
Stenosis	3 (0.6%)	16 (3.4%)	0.004
Aneurysm	20 (4.2%)	23 (4.9%)	0.755
Haematoma	45 (9.5%)	9 (1.9%)	0.002
PTA	20 (4.2%)	7 (1.5%)	0.015
Stenting	23 (4.9%)	23 (4.9%)	1.00
Iliac artery			0.343
Rupture	4 (0.8%)	3 (0.6%)	1.000
Dissection	6 (1.3%)	11 (2.3%)	0.302
Stenting	4 (0.8%)	7 (1.5%)	0.549
Aorta			
Stenting	0	0	–
Urgent vascular surgery	13 (2.8%)	5 (1.1%)	0.077

PTA, percutaneous transluminal angioplasty.

endovascular aortic aneurysm repair trial[22] randomized 150 patients to surgical or percutaneous vascular closure with either Prostar XL or Perclose ProGlide. All patients had large vascular access (21-Fr sheath system). Sub-analysis of the two percutaneous closure device arms, demonstrated increased vascular complication rates with the Prostar XL device when compared with the Perclose ProGlide device. Similar findings were reported in a retrospective analysis of TAVI patients indicating increased hazard of vascular complications with Prostar XL device.[23] The present study further expands these initial findings and suggests that even with the use of expandable sheaths and smaller delivery systems—there is an increased vascular complications risk with Prostar XL-based vascular closure strategy.

The enhanced efficacy of Perclose ProGlide-based vascular closure strategy that was demonstrated in the present study may be attributed to inherent differences in the design and characteristics of the two closure devices. The Prostar XL device features four needles (on both ends of two polyester sutures) which are delivered simultaneously outward from within the arterial lumen. Conversely, the Perclose ProGlide device delivers only two needles (on both ends of one polypropylene monofilament suture), so for pre-closing an arterial access, typically two Perclose ProGlide devices are deployed sequentially in 'crosshair approach' (10 and 2 o'clock). Thus, suboptimal positioning of the Prostar device against the arterial wall may result in mal-deployment of both sutures as all needles (and sutures) are deployed at once. Conversely, with a Perclose

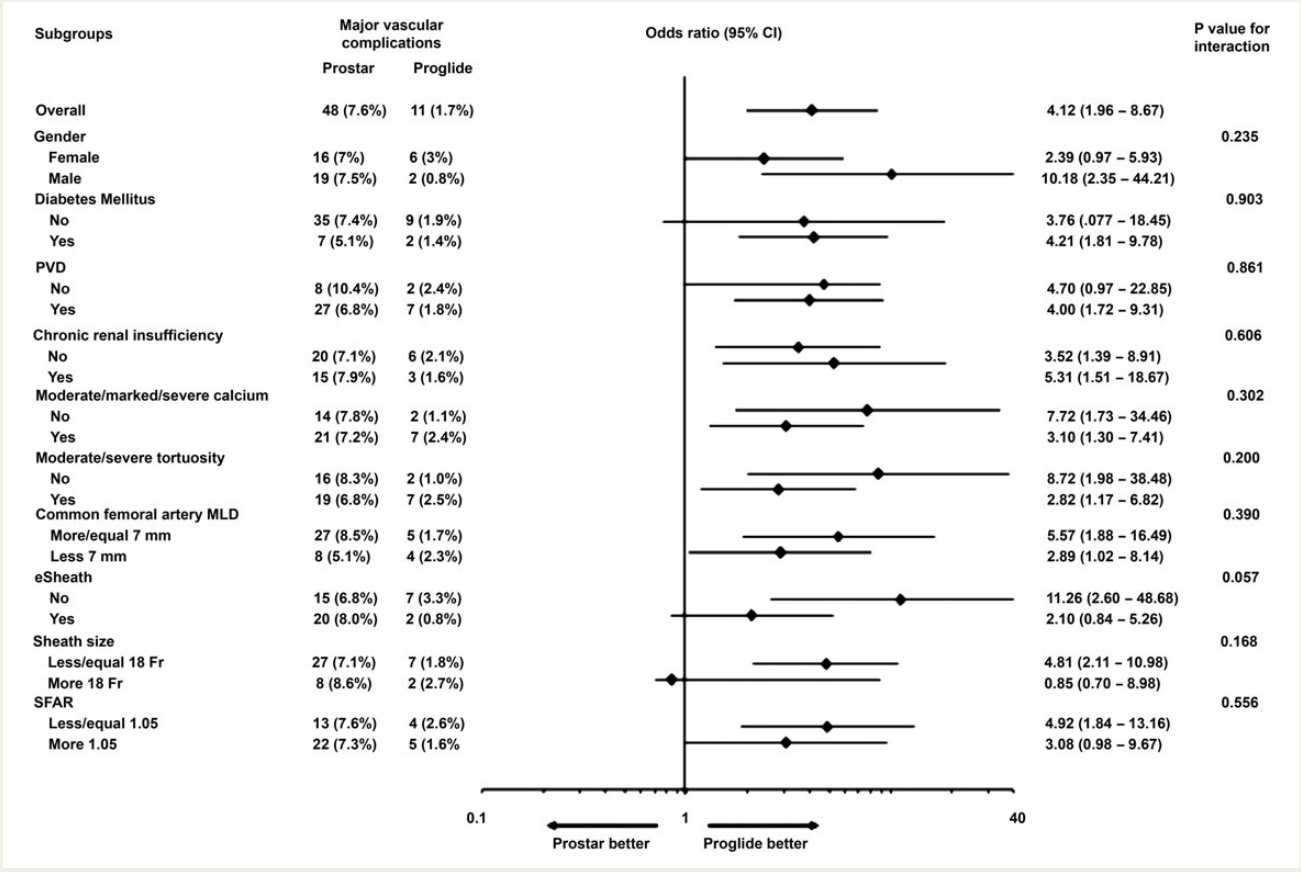

Figure 3 Sub-group analysis for the rate of major vascular complications. Sub-group analyses are shown for major vascular complications among patients treated by Prostar XL- vs. Perclose ProGlide-based strategy. Horizontal lines indicate 95% confidence intervals. The *P*-value for interaction represents the likelihood of interaction between the variable and the relative treatment effect.

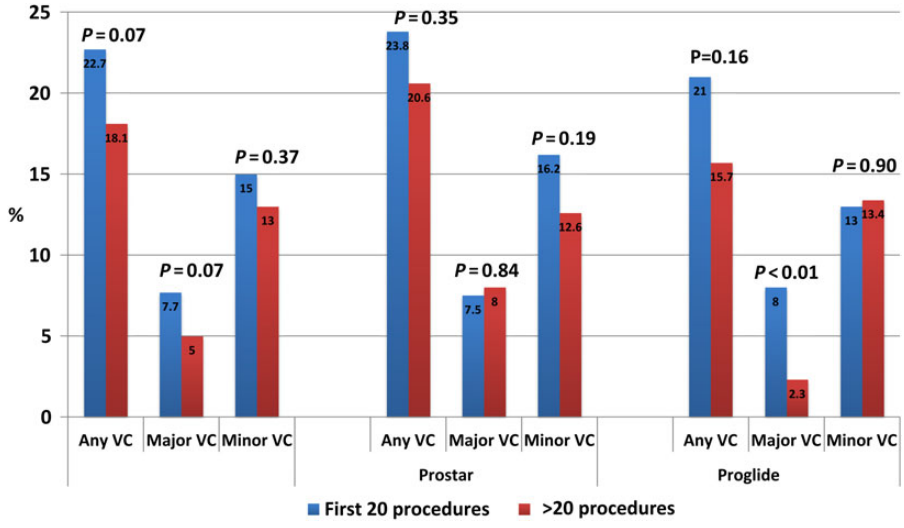

Figure 4 Rates of vascular complications according to center experience. VC, vascular complications.

ProGlide approach, each of the two sutures is deployed independently thus lowering the risk of a two-suture failure. Furthermore, identification of suture failure or needle 'miss-firing' in ProGlide can be corrected by adding a third device. In support of this hypothesis, the data from the present study indicate that the difference between the two devices is due to failed haemostasis. Furthermore, this hypothesis might also explain the bleeding patterns in both groups. Prostar use was associated with higher rates of major bleeding which may be a result of two-suture failure. Conversely, ProGlide use was associated with higher minor bleeds which may be associated with single suture failure. Additional signal that might suggest that the increased risk with Prostar might be related to the device itself is the lack of any 'learning-curve' effect in the use of Prostar. While there was a significant decrease in the rates of major vascular complications after the initial 20 cases in the ProGlide group, no such pattern was found in the Prostar group.

The higher rates of major vascular complications in the Prostar group contributed to higher incidence of bleeding events and periprocedural acute kidney injury. Several prior reports have shown the strong association between vascular complications and bleeding, and have found correlation between significant bleeding complications and increased mortality.[24–26] The increased incidence of kidney injury found in the present study may be associated with vascular complications by several mechanisms; first, the increased bleeding and transfusions may increase the risk for renal failure, second, potential transient hypotensive episode during the acute period of the vascular complication may further increase the risk for kidney injury. Finally, the interventions performed for treating the vascular complications involve injection of additional contrast dye and perhaps may require urgent surgery for vascular repair—all of which further increase the risk for kidney injury. Indeed, a similar association between vascular complications, bleeding and acute kidney injury has been previously demonstrated in TAVI patients.[9] Strong correlation between major vascular complications, bleeding events and mortality, was demonstrated in prior studies.[9,10] However, the present analysis did not demonstrate any mortality difference between the two groups despite a 4-fold increase in major vascular complications in Prostar group.

Limitations

This study was a nonrandomized, observational study and thus suffers from potential selection and ascertainment bias despite propensity-score matching. Given the retrospective nature of this study, several factors with potential to influence outcome could have not been collected. These include number of devices used or supplemental use of Angio-Seal (St Jude Medical, St Paul, MN, USA) (especially for the Perclose ProGlide group) and assessment of the VARC-2 vascular complication end point of 'Percutaneous closure device failure' which was impossible to retrieve retrospectively. However, the purpose of the current study was to compare two strategies of using either VCD irrespective of the number of devices used. Comparison of mortality rates is limited by the lack of data regarding time to events and censoring and by the fact that this study was underpowered to assess this end point, therefore, it was not possible to perform an adjusted analysis of mortality. Although all end points were reported according to the VARC-2 definitions, end points were reported by each site and no adjudication was performed. Finally, no computed tomography core lab was used in this study and vessel characteristics were based on individual site measurements.

Conclusions

Among a well-matched TAVI patient population, the rates of any vascular complication was comparable between the two VCD. However, a Perclose ProGlide-based vascular closure strategy was associated with lower rates of major vascular complications, bleeding and kidney injury when compared with Prostar XL-based vascular closure strategy. Despite these adverse events, mortality rates were comparable between the two vascular closure strategies.

Authors' contributions

M.B., I.B., D.D., S.B.: performed statistical analysis. I.M.B., M.B., J.M.-M.D.N., Y.A., C.N., F.D., A.S., M.S., K.S., F.D.R., H.J., T.M., N.S., S.I., D.D.: acquired the data. I.B., D.D., M.B.: conceived and designed the research. I.M.B., M.B., J.W., J.M.-M.D.N., Y.A., A.L., C.N., F.D., A.S., K.S., S.B., M.S., F.D.R., C.T., H.J., T.M., D.H., N.S., V.G., S.B., D.T., S.I., R.R.M., A.V., H.T., R.L., A.C., D.D.: drafted the manuscript. I.B., M.B., D.T., S.I., R.R.M., J.W., A.C., A.V., H.T., V.G., R.L., D.D.: made critical revision of the manuscript for key intellectual content.

Supplementary material

Supplementary material is available at *European Heart Journal* online.

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