Catheterization and Cardiovascular Interventions

WILEY

ORIGINAL ARTICLE - CLINICAL SCIENCE OPEN ACCESS

Impact of Sheath Type on Vascular and Bleeding Complications After Transcatheter Aortic Valve Replacement: A Post Hoc Analysis From the MARVEL Registry Study

Emily Pan[1,2] | Herbert G. Kroon[3] | Pim A. L. Tonino[4] | Giovanni Amoroso[5] | Mika Laine[6] | Evald H. Christiansen[7] | Stefan Toggweiler[8] | Jur Ten Berg[9] | Markus Malmberg[2] | Ton Slagboom[5] | Noriaki Moriyama[6,10] | Christian J. Terkelsen[7] | Federico Moccetti[8] | Livia Gheorghe[9,11] | Darra Bigelow[10] | John Webb[12] | David Wood[12] | Nicholas Van Mieghem[3] | Mikko Savontaus[2]

[1]Department of Surgery, Central Finland Hospital Nova, Jyväskylä, Finland | [2]Department of Cardiology, Turku University Hospital, Turku, Finland | [3]Department of Cardiology, Erasmus University Medical Center, Rotterdam, The Netherlands | [4]Department of Cardiology, Catharina Hospital, Eindhoven, The Netherlands | [5]Department of Cardiology, Onze Lieve Vrouwe Hospital, Amsterdam, The Netherlands | [6]Department of Cardiology, Helsinki University Hospital, Helsinki, Finland | [7]Department of Cardiology, Aarhus University Hospital, Aarhus, Denmark | [8]Department of Cardiology, Luzern Kantonsspital, Luzern, Switzerland | [9]Department of Cardiology, St. Antonius Hospital, Utrecht, The Netherlands | [10]Clinical and Medical Affairs, Teleflex Inc. | [11]Department of Cardiology, Shonan Kamakura General Hospital, Kamakura, Japan | [12]Department of Cardiology, St. Paul's Hospital, Vancouver, British Columbia, Canada

Correspondence: Mikko Savontaus (Mikko.Savontaus@tyks.fi)

Received: 13 April 2024 | **Revised:** 21 October 2024 | **Accepted:** 22 December 2024

Keywords: outcome | sheath type | transcatheter aortic valve replacement | vascular closure device | vascular complications

ABSTRACT

Background: Vascular and bleeding complications remain a concern after transfemoral transcatheter aortic valve replacement (TAVR). The impact of the sheath type on these complications remains unclear.

Methods: The prospective MARVEL registry study analyzed enrolled 500 patients undergoing large-bore transfemoral procedures and arteriotomy closure with the MANTA vascular closure device from 10 hospitals in Europe and Canada. We stratified these patients according to type of sheath used (expandable or conventional). A propensity-matched analysis was performed using VARC-2 major or minor vascular and bleeding complications as the primary endpoint. The secondary endpoint was time to hemostasis.

Results: We identified 196 propensity-matched pairs. Major vascular complications occurred in 3.6% in the expandable sheath group and 4.1% in the conventional sheath group ($p = 1.0$). Minor vascular complications occurred in 5.6% in the expandable sheath group and 4.6% in the conventional sheath group ($p = 0.819$). There were no significant differences in bleeding complications between groups. Time to hemostasis after MANTA closure was significantly shorter in the expandable sheath group (30 vs. 60 s, $p < 0.001$).

Conclusions: A propensity-matched analysis demonstrated no significant differences in vascular complication rates with MANTA arteriotomy closure after removal of large bore expandable or conventional sheaths. Time to hemostasis was significantly shorter in the expandable sheath group.

Abbreviations: ACT, active clotting time; BMI, body mass index; CEC, Clinical Event Committee; CI, confidence interval; IQR, interquartile range; MARVEL, Manta Registry for Vascular Large-bore Closure; OR, odds ratio; PSM, propensity score matching; SFAR, the Sheath to Femoral Artery Ratio; STS, Society of Thoracic surgeons; TAVR, transcatheter aortic valve replacement; THV, transcatheter heart valve; VARC-2, Valve Academic Research Consortium-2 criteria.

1 | Introduction

Minimally invasive catheter-based procedures have been a significant breakthrough in the field of cardiovascular medicine and have become a standard of care or as an alternative to conventional surgical approaches in many conditions. These procedures usually require large-bore sheaths for transfemoral artery access. Transcatheter aortic valve replacement (TAVR) is arguably the most common large-bore arterial intervention. Despite refinements in devices and operator techniques, the incidence of vascular complications persists during these interventions, contributing to increased morbidity and mortality [1, 2].

Sheath to vascular diameter ratio has been shown to be a major determinant of vascular trauma [1]. Therefore, new generation transcatheter heart valve (THV) systems are designed to be used via smaller bore-size sheaths. An alternative strategy is the use of expandable sheaths facilitating the insertion of the sheath and THV. Recent TAVR trials have reported major vascular complications between 2.0% and 7.9% in lower-risk patients [3–6]. However, there is a paucity of data comparing vascular complications between conventional sheaths and expandable sheaths.

The use of percutaneous vascular closure devices is currently standard of care for large bore access closure. The percutaneous MANTA Vascular Closure Device is a bovine collagen-based, self-resorbable technology that has been specifically designed for large-bore arteriotomies [7]. The Manta Registry for Vascular Large-bore Closure (MARVEL) trial was a prospective real-world registry trial of 500 patients, which reported low rates of major or minor vascular complications after percutaneous transfemoral large-bore arterial intervention [8]. In this substudy of MARVEL, we compare the outcomes between expandable and conventional sheaths in the context of MANTA closure.

2 | Methods

2.1 | Patient Selection and Study Protocol

Primary outcome and study design of the MARVEL trial have been described previously [7–9]. In brief, 500 patients underwent complete percutaneous transfemoral large-bore arterial intervention and subsequent arteriotomy closure with the MANTA device in Canada, Denmark, Netherlands, Finland, and Switzerland. For the current substudy, 21 patients with sheathless or unknown type of sheath were excluded, leaving 479 patients for the final analysis (Figure 1). The sheath selection was per operator's discretion and generally determined by the type of THV used.

All patients were evaluated by a multidisciplinary heart team. All participating operators had performed at least 10 MANTA closures before study entry. Vast majority, 99%, of the procedures in the study were TAVR, in addition, there were two balloon aortic valvuloplasties, one mechanical circulatory support, and one endovascular aneurysm repair included. Pre-procedural planning with multidetector computed tomography was mandatory for all TAVR procedures and recommended for other interventions. Relative exclusion criteria for MANTA use were per operator's discretion and included (1) excessive calcification of the access vessel; (2) severe peripheral artery disease precluding safe introduction of a large arterial sheath; (3) marked tortuosity of the femoral or iliac artery; (4) body mass index > 40 kg/m^2; (5) body mass index < 20 kg/m^2; and (6) uncontrolled hypertension at baseline defined by a systolic blood pressure > 180 mmHg.

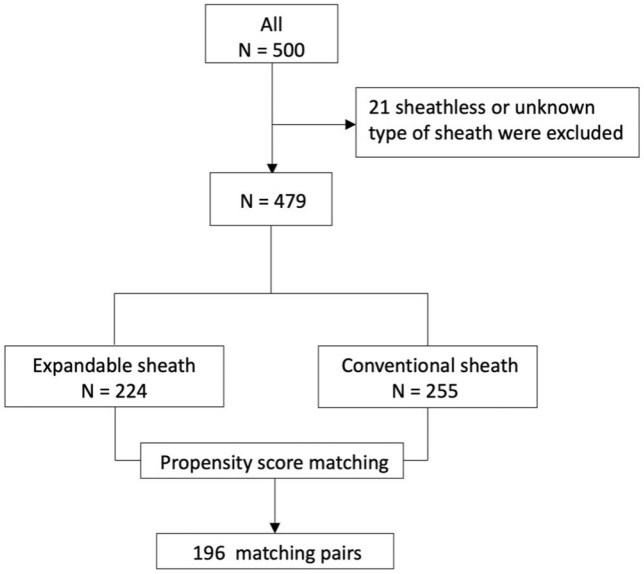

FIGURE 1 | A flowchart of the study.

Unfractionated heparin was used in all operations and target activated clotting time at the time of MANTA closure was required to be < 250 s. Protamine use was per operator's decision. A femoral angiogram post-MANTA deployment was recommended for all patients. The MANTA access site was examined immediately, 24 h later and before hospital discharge. A clinical follow-up was performed at 30 days.

All patients provided written informed consent for the index operation and trial enrollment. The study was conducted in accordance with the 1975 Declaration of Helsinki, Good Clinical Practice principles and current International Standard of Clinical Investigations of medical devices for human subjects (ENISO 14155:2011). Each institution site had an approval from the local institutional review board. Teleflex Inc. provided financial support to carry out the study, but was not involved with data acquisition, statistical analysis nor manuscript preparation.

2.2 | Definitions

The primary endpoint was the occurrence of access site related vascular or bleeding complications up to 30 days from the index procedure. Procedural and access site-related complications were graded according to the Valve Academic Research Consortium-2 criteria (VARC-2), which was the standard at the time of data collection of the study [10]. The secondary endpoint was time to hemostasis after deployment of the MANTA (defined as the elapsed time from the withdrawal of the MANTA sheath from the artery to observed arterial hemostasis, observed arterial hemostasis was defined as no or minimal subcutaneous oozing, and the absence of expanding hematoma).

Successful hemostasis was defined as hemostasis within 10 min after large bore sheath removal. Femoral artery calcification at the access site level was classified according to the semi-quantitative MANTA Femoral Artery Calcification Score and the following: Stage 0 – No calcification; Stage 1 – Small calcium spots dispersed over the vessel surface; Stage 2 – Calcium plaques dispersed over the vessel surface; Stage 3 – Large calcium plaque at the posterior wall; Stage 4 – Large calcium plaque at the anterior wall; Stage 5 – Excessive and circumferential calcium. Small femoral artery was defined as femoral artery smaller than MANTA device application. High-risk patients were defined as having one of the following: MANTA size mismatch, BMI < 20 or $> 40\,kg/m^2$, systolic pressure > 180 mmHg, a history of peripheral artery disease, active clotting time (ACT) > 250 s, small femoral artery size compared to the MANTA device being used and significant calcification.

All adverse events associated with the MANTA access site, including vascular and bleeding complications, were adjudicated by an independent Clinical Event Committee (CEC) according to VARC-2 criteria [10]. Minor bleeding events and hematomas that did not require treatment or required only manual or mechanical compression were not reviewed or adjudicated by the CEC. Device-related adverse events that occurred between 30 days and 12 months were also adjudicated by the CEC.

2.3 | Statistical Analysis

For the baseline analyses, continuous variables were presented as median with interquartile range (IQR). Categorical variables were reported as frequencies with percentages. Fisher's exact test was used for dichotomous variables or if $n < 5$. χ^2 test was used for categorical variables in the unmatched cohort and McNemar's test used for matched cohort. Continuous variables were compared using Student's t test, if normally distributed, and Mann–Whitney U test, if not normally distributed. To minimize the effect of selection bias, we performed propensity score matching (PSM) with nearest-neighbor method in 1:1 ratio and a caliber width of 0.2. The following variables were included in the PSM: age, sex, BMI, calcium score, small femoral artery, use of antiplatelet medication (Adenosine diphosphate receptor/P2Y12 inhibitors, acetylsalicylic acid), and use of anticoagulation medication (heparin, warfarin, direct oral anticoagulants). The standardized mean difference for each covariate is presented in Figure S1. Logistic regression analyses were used to evaluate the relationship between types of sheaths and primary and secondary outcomes, reported as odds ratios (ORs) with 95% confidence interval (CI). Linear regression was used to explore the correlation between continuous outcome and different sheaths and reported with R^2 and p value with 95% CI. All tests were two-tailed, and p value of < 0.05 were considered statistically significant. p values and 95% CIs presented in this study have not been adjusted for multiplicity, and therefore inferences drawn from these statistics may not be reproducible.

PSM was performed using MatchIt-package from R version 4.3.2 for MacOS. The balance was assessed using univariate balance summary statistics. Other statistical analyses were performed using IBM SPSS Statistics version 29 (IBM).

3 | Results

3.1 | Patient and Procedural Characteristics

In total, 224/479 (46.7%) procedures were performed with an expandable sheath and 255/479 (53.2%) with a conventional sheath. After PSM, a total of 196 pairs were formed (Figure 1). The baseline characteristics for the entire cohort and different sheaths before and after PSM are presented in Table 1. Patients with expandable sheaths were more often male (59.8% vs. 49.8%), had lower BMI (25.8 vs. 27.1, $p = 0.017$) and had less anticoagulation medication (68.3% vs. 82.7%, $p < 0.01$), mainly clopidogrel (33.9% vs. 43.1%, $p = 0.048$), and significantly less small-sized femoral arteries (1.3% vs. 5.9%, $p = 0.01$). There were no statistically significant differences between the groups in age, past medical history, previous cardiac procedures, and the use of acetylsalicylic acid, heparin, or oral anticoagulation. None of the baseline characteristics differed significantly after PSM (all $p > 0.05$). Apart from smaller vessels in the conventional group, the number and risk-profile of patients who experienced vascular complications did not differ between the types of sheath (Table S1).

There were significant differences in the types of THVs used with expandable sheaths as compared with conventional sheaths. Most of the TAVR procedures in the study used either the Edwards Sapien 3 valve or the Medtronic Evolut valve. Expandable sheaths were used almost exclusively in Sapien 3 procedures and conventional sheaths almost exclusively in Evolut procedures (Table S2). A minority of procedures used other THVs and both sheath types were used in these cases.

Table 2 presents the procedural characteristics between the sheath types before and after PSM. The sheath outer diameter during THV insertion was slightly larger in expandable vs conventional sheaths (23 vs. 22 Fr, $p < 0.01$) and a larger MANTA device was more often used in procedures with expandable sheaths (98.7% vs. 94.1%, $p = 0.01$). The procedure time was significantly shorter for procedures using expandable sheaths (59.0 vs. 62.0 min, $p < 0.01$). In addition, both tissue depth (3.5 vs. 4.0 mm, $p = 0.007$) and deployment depth (5.0 vs. 5.2 mm, $p < 0.01$) were significantly shallower and the activated clotting time just before closure shorter (160.0 vs. 178.0 s, $p < 0.01$) in procedures using expandable sheaths.

3.2 | Outcomes

There were no significant differences in the CEC-adjudicated VARC-2 major or minor vascular complications before (9.4% vs. 9.4%, $p = 1.00$) or after (9.2% vs 8.7%, $p = 1.00$) PSM between the expandable and conventional sheath groups (Table 3). For bleeding complications, there were also no differences in life-threatening, major or minor bleeding events between the two groups before (4.5% vs. 4.7%, $p = 1.00$) or after (4.1% vs. 4.1%, $p = 1.00$) PSM (Table 3).

There were 21 major or life-threatening bleeding or vascular complications according to VARC-2 criteria, 8 in expandable and 13 in conventional sheaths. The detailed descriptions of these complications, their treatments and outcomes are

TABLE 1 | Patient characteristics and medication use at baseline between expandable and conventional sheath groups before and after propensity score matching.

	Before propensity score matching ($n = 479$)			After propensity score matching ($n = 392$)		
	Expandable	**Conventional**	***p* value**	**Expandable**	**Conventional**	***p* value**
Age	82.0 (78.0–85.0)	82.0 (77.0–85.0)	0.562	82.0 (78.0–85.0)	82.0 (77.2–85.0)	0.925
Male	134 (59.8%)	127 (49.8%)	0.034	117 (51.0%)	100 (59.7%)	0.104
BMI	25.8 (23.5–28.9)	27.1 (24.2–30.2)	0.017	26.0 (23.7–29.4)	27.0 (23.8–29.8)	0.578
History of						
Hypertension	136 (60.7%)	173 (67.8%)	0.266	125 (64.1%)	130 (66.7%)	0.670
Periferal artery disease	14 (6.3%)	25 (9.8%)	0.183	14 (7.3%)	20 (10.3%)	0.370
GFR < 60	109 (48.9%)	108 (42.5%)	0.168	95 (48.7%)	83 (42.6%)	0.263
Cerebrovascular accident	31 (14.0%)	52 (20.4%)	0.071	29 (14.9)	41 (20.9%)	0.147
Previous						
CABG	27 (12.1%)	22 (8.6%)	0.229	26 (13.3%)	16 (8.2%)	0.105
PCI	60 (26.8%)	79 (31.0%)	0.364	57 (29.1%)	58 (29.6%)	1.000
Anticoagulation medication	153 (68.3%)	211 (82.7%)	<0.001			
acetylsalicylic acid	119 (53.1%)	156 (61.2%)	0.079	119 (60.7%)	118 (60.2%)	1.000
clopidogrel	76 (33.9%)	110 (43.1%)	0.048	75 (38.3%)	80 (40.8%)	0.680
thienopyridine	4 (3.0)	1 (0.7%)	0.199	4 (0.5%)	1 (0.9%)	0.206
heparin	4 (1.8%)	8 (3.1%)	0.393			
unfractionated	1 (0.4%)	4 (1.6%)	0.377	1 (0.5%)	3 (1.5%)	0.372
LMWH	4 (1.8%)	4 (1.6%)	1.000	4 (2.0%)	3 (1.5%)	1.000
Oral anticoagulation	26 (11.6%)	35 (13.7%)	0.496			
acenocoumarol	20 (8.9%)	21 (8.2%)	0.870	17 (8.7%)	17 (8.7%)	1.000
fenprocoumon	2 (0.9%)	5 (2.0%)	0.457	1 (0.5%)	4 (2.0%)	0.372
other	4 (1.8%)	9 (3.5%)	0.274	4 (2.0%)	6 (3.1%)	0.751
Direct oral anticoagulation	23 (10.3%)	37 (14.5%)	0.169			
rivaroxaban	9 (4.0%)	16 (6.3%)	0.308	9 (4.6%)	16 (6.6%)	0.511
dabigatran	5 (2.2%)	7 (2.7%)	0.777	5 (2.6%)	6 (3.1%)	1.000
apixaban	8 (3.6%)	12 (2.5%)	0.649	8 (4.1%)	9 (4.6%)	1.000
edoxaban	1 (0.4%)	2 (0.8%)	1.000	1 (0.5%)	2 (1.0%)	1.000
Other anticoagulations	6 (2.7%)	4 (1.6%)	0.526	6 (3.1%)	2 (1.0%)	0.175
Small femoral artery size[a]	3 (1.3%)	25 (5.9%)	0.014	3 (1.5%)	4 (2.0%)	1.000
Artery calcification	9 (4.0%)	9 (3.5%)	0.814	6 (3.1%)	8 (4.1%)	0.787
c	2.7 (2.0–4.2)	2.8 (1.9–4.4)	0.908	3.5 (3.1–3.2)	3.5 (3.2–3.8)	0.863

Note: Data are presented as number (%) or median (interquartile range). Fisher's exact test or χ^2 test were used for categorical variables in the unmatched cohort and McNemar's test for matched cohort. Continuous variables were compared using Student's *t* test or and Mann–Whitney *U* test. No corrections for multiple testing were applied.

Abbreviations: BMI, body mass index; CABG, coronary artery bypass grafting; GFR, glomerular filtration rate; LMWH, low molecular weight heparin; PCI, percutaneous coronary intervention; STS Score, Society of Thoracic surgeons Adult Cardiac Surgery Risk Score.

[a]Small femoral artery size, defined as where MANTA size exceeds femoral artery size.

TABLE 2 | Procedural characteristics between expandable and conventional sheath groups.

	Before propensity score matching ($n = 479$)			After propensity score matching ($n = 392$)		
	Expandable	**Conventional**	***p* value**	**Expandable**	**Conventional**	***p* value**
Limb side			0.40			0.53
left	23 (10.3%)	33 (12.9%)		20 (10.2%)	25 (12.8%)	
right	201 (89.7%)	228 (87.1%)		176 (89.8%)	171 (87.2%)	
MANTA device size			0.01			< 0.01
14 Fr	3 (1.3%)	15 (5.9%)		2 (1.0%)	12 (6.2%)	
18 Fr	220 (98.7%)	239 (94.1%)		194 (99.0%)	183 (93.8%)	
Sheath outer diameter (Fr)	23.0 (23.0–24.5)	22.0 (20.0–22.5)	< 0.01	23.0 (23.0–24.5)	21.0 (20.0–22.5)	< 0.01
Procedure			0.41			0.37
TAVR	223 (99.6%)	261 (98.8%)		195 (99.5%)	193 (98.5%)	
EVAR	0 (0.0%)	2 (0.8%)		0 (0%)	2 (1.0%)	
BAV	1 (0.2%)	1 (0.2%)		1 (0.5)	1	
Procedure time (min)	59.0 (43.0–73.0)	62.0 (50.0–82.0)	< 0.01	60.0 (45.0–74.75)	62.0 (48.25–81.75)	0.08
Tissue depth (mm)	3.5 (2.75–4.0)	4.0 (3.0–4.5)	< 0.01	3.5 (3.0–4.0)	3.5 (2.5–4.5)	0.13
Deployment depth (mm)	5.0 (4.0–5.5)	5.2 (4.5–6.0)	< 0.01	5.0 (4.0–5.5)	5.0 (4.5–6.0)	< 0.01
Activated clotting time before closure (s)	160.0 (133.0–201.75)	178.0 (142.0–226.0)	< 0.01	158 (131–198)	178 (140–220)	< 0.01
Protamine used						
before closure	145 (64.7%)	146 (57.3%)	0.11	129 (65.8%)	109 (55.6%)	0.05
after closure	22 (9.8%)	32 (12.5%)	0.39	16 (8.2%)	26 (13.3%)	0.14
Pressure bandage > 3 h	23 (10.6%)	42 (16.5%)	0.08	23 (12.0%)	30 (15.3%)	0.38

Note: Data are presented as number (%) or median (interquartile range). Fisher's exact test or χ^2 test were used for categorical variables in the unmatched cohort and McNemar's test for matched cohort. Continuous variables were compared using Student's *t* test or and Mann–Whitney *U* test. No corrections for multiple testing were applied.

Abbreviations: BAV, balloon aortic valvuloplasty; EVAR, endovascular aneurysm repair; Fr, French size; TAVR, transcatheter aortic valve replacement.

presented in Table S3. One patient (no. 7, expandable sheath) deceased due to vessel dissection and perforation from the access site resulting in major bleeding. Four major complications were caused by closure device failure (no. 12, 16, 20, and 21, all conventional sheaths). Overall, seven (1.5%) patients died within 30-days after the procedure, one of them (no. 7) was determined as a device-related event.

The hemostasis time was significantly shorter in the expandable sheath group both before (30 vs. 60 s, $p < 0.01$) and after PSM (30 vs. 60 s, $p < 0.01$). However, there were no differences in achieving successful hemostasis or having a hematoma requiring further treatment between different types of sheaths (Table 3). Figure 2 shows that 74.2% of patients with expandable sheath and 52.0% of patients with conventional sheath achieved hemostasis in less than 1 min in the unmatched population.

Logistic regression analysis revealed no associations between different types of sheaths and VARC-2 vascular complications (OR 0.94 [0.469–1.881]), bleeding complications (OR 0.90 [0.40–2.23]) or 30-day mortality (OR 2.54 [0.487–13.2]), all $p > 0.05$, before or after PSM (data not shown). There were very weak correlation between type of sheaths and hemostasis time before PSM ($R^2 = 0.01$, $p = 0.02$ [15.8–180.5]), and no significant correlation after PSM ($R^2 = 0.01$, $p = 0.09$ [−133.3–9.2]).

4 | Discussion

This subanalysis of the prospective MARVEL study is a propensity matched comparison of MANTA arteriotomy closure after expandable or conventional large bore sheaths. There were no significant differences in the primary endpoint of major or minor vascular or bleeding complications albeit the time to hemostasis after MANTA deployment was shorter in the expandable sheath group, (30 vs. 60 s, $p < 0.001$).

Our findings add to the existing literature on the role of large-bore sheaths and closure devices on vascular complications during TAVR procedures. Only one previous study has directly compared expandable and conventional sheaths in TAVR procedures [11]. This retrospective propensity-matched analysis

TABLE 3 | Comparison of outcomes and complications between expandable and conventional sheath groups.

	Before propensity score matching ($n = 479$)				After propensity score matching ($n = 392$)			
	Expandable	Conventional	Rate difference (%)	p value (95% CI)	Expandable	Conventional	Rate difference (%)	p value (95% CI)
Primary endpoints								
Vascular complications (VARC-2)	21 (9.4%)	24 (9.4%)	0.0	1.00 (−5.5–5.5)	18 (9.2%)	17 (8.7%)	0.5	1.00 (−5.4–6.4)
Minor	13 (5.8%)	11 (4.3%)	1.5	0.53 (−2.5–5.5)	11 (5.6%)	9 (4.6%)	0.0	0.82 (−3.5–5.5)
Major	8 (3.1%)	13 (5.1%)	2.0	0.51 (−5.3–2.2)	7 (3.6%)	8 (4.1%)	0.5	1.00 (−4.4–3.4)
Bleeding complications (VARC-2)	10 (4.5%)	12 (4.7%)	0.2	1.00 (−4.1–3.6)	8 (4.1%)	8 (4.1%)	0.0	1.00 (0.0–0.0)
Minor	4 (1.8%)	2 (0.8%)	1.0	0.43 (−1.0–3.0)	3 (1.5%)	2 (1.0%)	0.5	1.00 (−1.7–2.7)
Major	5 (2.2%)	5 (2.0%)	0.2	1.00 (−2.3–2.9)	4 (2.0%)	4 (2.0%)	0.0	1.00 (0.0–0.0)
Life-threatening or disabling	1 (0.4%)	5 (2.0%)	1.6	0.22 (−3.5–0.5)	1 (0.5%)	2 (1.0%)	0.5	1.00 (−2.2–1.2)
Secondary endpoints								
Hemostasis time (s)	30.0 (3.5–65.0)	60.0 (38.0-180.0)		< 0.01	30.0 (3.5–65.0)	60.0 (38.0–180.0)		< 0.01
Successful hemostasis[a]	211 (94.2%)	240 (94.1%)	0.1	1.00 (−17.3–17.5)	187 (95.4%)	185 (94.4%)	1.0	0.82 (−18.3–20.3)
Hematoma that required further treatment after procedure								
In hospital	8 (3.6%)	6 (2.4%)	1.2	0.59 (−1.9–4.3)	6 (3.1%)	5 (2.6%)	0.5	1.00 (−2.8–3.8)
After discharge	3 (1.3%)	1 (0.4%)	1.1	0.34 (−0.7–2.6)	2 (1.0%)	1 (0.5%)	0.5	1.00 (−1.2–2.2)

Note: Data are presented as number (%) or median (interquartile range). Fisher's exact test or χ^2 test were used for categorical variables in the unmatched cohort and McNemar's test for matched cohort. Continuous variables were compared using Student's t test or and Mann–Whitney U test. No corrections for multiple testing were applied.
Abbreviation: VARC2, Valve Academic Research Consortium 2.
[a]Defined as successful hemostasis within 10 min.

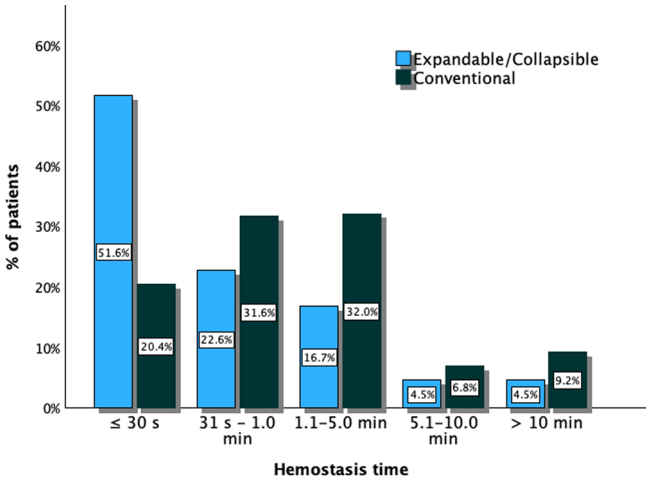

FIGURE 2 | Time to achieve hemostasis in patients (shown in percentage) that had either expandable sheath or conventional sheath. [Color figure can be viewed at wileyonlinelibrary.com]

compared expandable and conventional sheaths when using suture-based closure devices. The results demonstrated a non-significant trend (7.6% vs. 12.7%) toward fewer VARC-3 major vascular complications when using conventional sheaths. Major RCTs have reported major vascular complication rates of 3.8% and 6% for low- and intermediate-risk patients using conventional sheaths with the Evolut valve [5, 6]. For expandable sheaths with the balloon expandable TAVR, RCTs have shown major vascular complication rates of 2.2% and 7.9% for low- and intermediate-risk patients [3, 4]. In a population with median Society of Thoracic Surgery (STS) score of 2.7%, 4.1% of patients treated with conventional sheaths and 3.6% of patients treated with expandable sheaths were reported to have major vascular complications. Our analysis demonstrated similar rates of major vascular complications. In our study, majority of self-expanding sheaths (87%) were used with the Sapien balloon-expandable THV and majority of conventional sheaths (70%) were used with the Evolut self-expanding THV. Although our study was not a comparison of different THV types, this supports the notion that no significant differences in vascular complications exist between these two THV systems. This observation is in line with the recent SMART trial, where no differences in major vascular complications were observed between the Sapien and Evolut THVs [12].

We have previously reported the results from the current data set with regard to the efficacy of MANTA closure device, and demonstrated a relatively low level of major (4%) and minor (5.6%) MANTA access site complications [8]. Several previous studies have compared the MANTA plug-based closure device with suture-based devices. Most studies were observational and have reported either no statistically significant differences between the two strategies or a reduction in vascular complications with MANTA [13–15]. A recent study analyzing observational and randomized studies comparing MANTA-based and suture device-based closure strategies demonstrated that while some observational studies point to favorable outcomes for large-bore vascular closure with the MANTA-based technique, RCT studies demonstrate that this strategy is associated with more access-site related vascular complications [16–18].

The conventional and expandable sheaths have different design strategies to minimize vascular complications. The use of conventional sheaths in the context of self-expanding valves allows for the possibility to use integrated sheaths, resulting in lower sheath outer diameter. In our data, 70% of the sheaths in the conventional sheath group were integrated resulting in a statistically significant reduction is sheath outer diameter as compared with the expandable sheaths. Previous studies have demonstrated the Sheath to Femoral Artery Ratio (SFAR) as a risk factor for vascular complications [1]. However, if a pre- or postdilatation is required during the TAVR procedure, the integrated sheath has to be exchanged for a conventional sheath of the same size, possibly increasing the risk of vascular trauma especially if the peripheral vessels are highly calcified [1]. Expandable sheaths have the advantage of needing only one sheath with an initial outer diameter of 14 or 16 F. However, insertion of the THV will expand the sheath resulting in a final sheath outer diameter of 23–24.5 F and thus higher SFAR. In addition, the inflating mechanism of expandable sheaths may in rare cases predispose to vascular complications [19].

4.1 | Study Limitations

The current study is a post hoc analysis of a multicenter, prospective study without randomization and could be prone to selection bias. However, its multicenter design and only relative exclusion criteria make it a realistic reflection of contemporary clinical practice. There were significant differences in the types of THVs used with expandable sheaths as compared with conventional sheaths, which may have affected the results (Table S2).

5 | Conclusions

This prospective, multicenter propensity-matched analysis showed no differences in vascular complications with MANTA large bore closure after conventional and expandable sheaths. Sheath type in TAVR procedures should thus be individually selected, based on patient-specific factors and the type of THV.

Conflicts of Interest

Markus Malmberg has received educational grants from Medtronic, Edwards Lifesciences, and Boston Scientific. Nicolas Van Mieghem received research grant support from Abbott Vascular, Boston Scientific, Medtronic, Edwards Lifesciences, Daiichi Sankyo, Astra Zeneca, Teleflex, PulseCath BV and advisory fees from Anteris, JenaValve, Siemens, Feops, Materialise, Abbott Vascular, Boston Scientific, Medtronic, Daiichi Sankyo, Amgen, Teleflex, PulseCath BV. Noriaki Moriyama has received honoraria from Edwards Lifesciences, Medtronic, Abbott, Daiichi Sankyo, and Boehringer Ingelheim. Mikko Savontaus received advisory fees from Medtronic and Boston Scientific. Stefan Toggweiler has received honoraria from Medtronic, Boston Scientific, Biosensors, Hi-D Imaging, Abbott Vascular, Medira, Shockwave, Teleflex, atHeart Medical, Cardiac Dimensions, Polares Medical, Amarin, Sanofi, AstraZeneca, ReCor Medical, Daiichi Sankyo, has received institutional research grants from Edwards Lifesciences, Abbott Vascular, Boston Scientific, Fumedica, Novartis, Boehringer Ingelheim, Polares Medical, and holds equity in Hi-D Imaging.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

1. H. Ruge, M. Burri, M. Erlebach, and R. Lange, "Access Site Related Vascular Complications With Third Generation Transcatheter Heart Valve Systems," *Catheterization and Cardiovascular Interventions* 97, no. 2 (2021): 325–332, https://doi.org/10.1002/ccd.29095.

2. P. Généreux, J. G. Webb, L. G. Svensson, et al., "Vascular Complications After Transcatheter Aortic Valve Replacement," *Journal of the American College of Cardiology* 60, no. 12 (2012): 1043–1052, https://doi.org/10.1016/j.jacc.2012.07.003.

3. M. B. Leon, C. R. Smith, M. J. Mack, et al., "Transcatheter or Surgical Aortic-Valve Replacement in Intermediate-Risk Patients," *New England Journal of Medicine* 374, no. 17 (2016): 1609–1620, https://doi.org/10.1056/nejmoa1514616.

4. M. J. Mack, M. B. Leon, V. H. Thourani, et al., "Transcatheter Aortic-Valve Replacement With a Balloon-Expandable Valve in Low-Risk Patients," *New England Journal of Medicine* 380, no. 18 (2019): 1695–1705, https://doi.org/10.1056/nejmoa1814052.

5. J. J. Popma, G. M. Deeb, S. J. Yakubov, et al., "Transcatheter Aortic-Valve Replacement With a Self-Expanding Valve in Low-Risk Patients," *New England Journal of Medicine* 380, no. 18 (2019): 1706–1715, https://doi.org/10.1056/nejmoa1816885.

6. M. J. Reardon, N. M. Van Mieghem, J. J. Popma, et al., "Surgical or Transcatheter Aortic-Valve Replacement in Intermediate-Risk Patients," *New England Journal of Medicine* 376, no. 14 (2017): 1321–1331, https://doi.org/10.1056/nejmoa1700456.

7. L. van Gils, P. P. T. De Jaegere, G. Roubin, and N. M. Van Mieghem, "The MANTA Vascular Closure Device," *JACC: Cardiovascular Interventions* 9, no. 11 (2016): 1195–1196, https://doi.org/10.1016/j.jcin.2016.03.010.

8. H. G. Kroon, P. A. L. Tonino, M. Savontaus, et al., "Dedicated Plug Based Closure for Large Bore Access - The MARVEL Prospective Registry," *Catheterization and Cardiovascular Interventions* 97 (2020): 1270–1278, https://doi.org/10.1002/ccd.29439.

9. N. M. Van Mieghem, A. Latib, J. van der Heyden, et al., "Percutaneous Plug-Based Arteriotomy Closure Device for Large-Bore Access," *JACC: Cardiovascular Interventions* 10, no. 6 (2017): 613–619, https://doi.org/10.1016/j.jcin.2016.12.277.

10. A. P. Kappetein, S. J. Head, P. Genereux, et al., "Updated Standardized Endpoint Definitions for Transcatheter Aortic Valve Implantation: The Valve Academic Research Consortium-2 Consensus Document (VARC-2)," *European Journal of Cardio-Thoracic Surgery* 42, no. 5 (2012): S45–S60, https://doi.org/10.1093/ejcts/ezs533.

11. H. Ruge, M. Burri, M. Erlebach, and R. Lange, "Propensity Matched Analysis of Vascular Complications Using Integrated or Expandable Sheaths for TAVR," *Catheterization and Cardiovascular Interventions* 99, no. 5 (2022): 1611–1618, https://doi.org/10.1002/ccd.30088.

12. H. C. Herrmann, R. Mehran, D. J. Blackman, et al., "Self-Expanding or Balloon-Expandable TAVR in Patients With a Small Aortic Annulus," *New England Journal of Medicine* 390, no. 21 (2024): 1959–1971, https://doi.org/10.1056/NEJMoa2312573.

13. O. Dumpies, M. Kitamura, N. Majunke, et al., "Manta Versus Perclose ProGlide Vascular Closure Device After Transcatheter Aortic Valve Implantation: Initial Experience From a Large European Center," *Cardiovascular Revascularization Medicine* 37 (2022): 34–40, https://doi.org/10.1016/j.carrev.2021.06.134.

14. G. A. Medranda, B. C. Case, C. Zhang, et al., "Propensity-Matched Comparison of Large-Bore Access Closure in Transcatheter Aortic Valve Replacement Using MANTA Versus Perclose: A Real-World Experience," *Catheterization and Cardiovascular Interventions* 98, no. 3 (2021): 580–585, https://doi.org/10.1002/ccd.29786.

15. F. Biancari, H. Romppanen, M. Savontaus, et al., "MANTA Versus ProGlide Vascular Closure Devices in Transfemoral Transcatheter Aortic Valve Implantation," *International Journal of Cardiology* 263 (2018): 29–31, https://doi.org/10.1016/j.ijcard.2018.04.065.

16. M. Abdel-Wahab, P. Hartung, O. Dumpies, et al., "Comparison of a Pure Plug-Based Versus a Primary Suture-Based Vascular Closure Device Strategy for Transfemoral Transcatheter Aortic Valve Replacement: The CHOICE-CLOSURE Randomized Clinical Trial," *Circulation* 145, no. 3 (2022): 170–183, https://doi.org/10.1161/CIRCULATIONAHA.121.057856.

17. O. Dumpies, A. Jobs, D. Obradovic, et al., "Comparison of Plug-Based Versus Suture-Based Vascular Closure for Large-Bore Arterial Access: A Collaborative Meta-Analysis of Observational and Randomized Studies," *Clinical Research in Cardiology* 112, no. 5 (2023): 614–625, https://doi.org/10.1007/s00392-022-02145-5.

18. M. P. van Wiechen, D. Tchétché, J. F. Ooms, et al., "Suture- or Plug-Based Large-Bore Arteriotomy Closure," *JACC: Cardiovascular Interventions* 14, no. 2 (2021): 149–157, https://doi.org/10.1016/j.jcin.2020.09.052.

19. P. Savvoulidis, A. M. Nadir, A. Mechery, and S. N. Doshi, "A Very Rare Vascular Complication of the Edwards Expandable eSheath During Transcatheter Aortic Valve Replacement," *Catheterization and Cardiovascular Interventions* 101, no. 3 (2023): 660–667, https://doi.org/10.1002/ccd.30557.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.