STRUCTURAL HEART
2021, VOL. 5, NO. 1, 79–84
https://doi.org/10.1080/24748706.2020.1849882

ORIGINAL RESEARCH

Percutaneous Transaxillary versus Surgically-Assisted Transsubclavian TAVR: A Single Center Experience

Ben Wilkins, MD, Gintautas Bielauskas, MD, Giulia Costa, MD, Motoki Fukutomi, MD, Lars Søndergaard, MD, DMSc, and Ole De Backer, MD, PhD

The Heart Centre, Rigshospitalet, Copenhagen University Hospital, Copenhagen, Denmark

ABSTRACT

Background: Transfemoral access is the standard approach for transcatheter aortic valve replacement (TAVR). However, an important proportion of TAVR patients may not be considered for transfemoral access because of anatomic reasons – for these patients, an alternative access route must be considered. The objective of this study was to assess the safety and efficacy of percutaneous transaxillary TAVR as compared to surgically assisted transsubclavian TAVR and to report the feasibility of next-day discharge following this percutaneous approach.

Methods: Since January 2019, all transaxillary TAVR at our institution were performed using a standardized percutaneous approach – this was compared to our prior experience with transsubclavian TAVR via surgical cut down.

Results: Sixty-four patients underwent transsubclavian/axillary TAVR since 2014: 40 surgically assisted transsubclavian (2014–-2018) and 24 fully percutaneous transaxillary TAVR (2019–2020). Both groups had similar baseline characteristics. In the surgically assisted TAVR group, six major vascular complications were encountered and six patients were rehospitalized within 30 days after TAVR vs. no patients with a major vascular complication and one patient rehospitalized within 30 days in the percutaneous transaxillary group. Hospitalization was significantly shorter for patients treated by percutaneous vs. surgical approach (1.2 vs. 4.4 days; p <0.001). Twenty out of 24 percutaneous transaxillary TAVR patients (83%) were discharged the day after TAVR.

Conclusion: Percutaneous transaxillary TAVR is a safe and effective treatment option for patients not suitable for transfemoral TAVR. Significant reduction in hospital length-of-stay was noted in percutaneous transaxillary vs. surgically assisted transsubclavian TAVR.

Abbreviations: CABG: coronary artery bypass graft; ECG: electrocardiogram; LAD: left anterior descending; LIMA: left internal mammary artery; STS: Society of Thoracic Surgeons; TAVR: transcatheter aortic valve replacement; OAC: oral anticoagulation; PTA: percutaneous transluminal angioplasty; VARC: Valve Academic Research Consortium

ARTICLE HISTORY Received 8 June 2020; Revised 29 September 2020; Accepted 3 November 2020

KEYWORDS TAVR; alternative access; transaxillary; percutaneous; next-day discharge

Introduction

Percutaneous transfemoral access is the preferred approach for transcatheter aortic valve replacement (TAVR). For these cases, a standardized approach for post-TAVR care exists and safe and effective next-day discharge has been demonstrated.[1]

Alternative non-transfemoral access is needed in 5% to 15% of TAVR cases.[2,3] Alternative access can increase procedural complexity through surgically assisted subclavian, carotid, direct aortic, or transapical approach. Although these techniques have proven to be safe and effective, patients are typically hospitalized for a much longer time due to the more invasive nature of these procedures and the monitoring and care required following a surgical wound closure.[4,5]

This study aimed to assess the safety and efficacy of a standardized percutaneous transaxillary TAVR approach and to offer institutional comparison to previous experience with surgically assisted transsubclavian TAVR.

Materials and methods

Patient selection and data collection

All patients treated by transsubclavian or transaxillary TAVR, since the start of the TAVR program in 2008, were identified in the East-Denmark TAVR registry. Transfemoral access is the institutional norm for TAVR, augmented since 2018 with Shockwave-assisted intravascular lithotripsy (Shockwave Medical Inc., CA, USA) where necessary. The need for alternative access is decided by experienced TAVR operators on the basis of anatomic characteristics which include severe vascular calcification, insufficient lumen diameter, severe tortuosity, low likelihood of successful vascular closure, or limited percutaneous bail-out options. In general, patients with iliofemoral arterial lumen diameter < 5.0 mm and/or severe tortuosity in combination with heavy calcification are considered for alternative access TAVR. Beyond intravascular lithotripsy-assisted transfemoral TAVR, the first choice for alternative access is transaxillary/transsubclavian.[6] Additionally, transcaval and

CONTACT Ole De Backer ole.debacker@gmail.com The Heart Centre, Rigshospitalet, University of Copenhagen, Copenhagen 2100, Denmark.

transapical TAVR are currently also performed at our institution.

All transsubclavian cases were performed by surgical cut-down access until December 2018. From January 2019, a standardized percutaneous transaxillary TAVR approach was implemented at our institution. To account for the TAVR learning curve and higher risk population in the early TAVR period, only patients from 2014 until present were included in this study (Figure 1).

All patients were discussed by a multidisciplinary Heart Team and found eligible for TAVR based on age, surgical risk estimation, anatomical characteristics, frailty, etc. All baseline patient and procedural data were prospectively collected in the East-Denmark TAVR registry. Follow-up data were retrospectively (surgical cohort) and prospectively (percutaneous cohort) collected by use of the patient's electronic medical record. Definition of device success, early safety and clinical efficacy, as well as classification of adverse events were according to the Valve Academic Research Consortium (VARC) two criteria. All patients gave written informed consent for the procedure and the use of anonymous data for research; Institutional Review Board approval was not needed.

Procedural techniques

Details of the surgical access technique used for transsubclavian TAVR have been previously reported.[7] To summarize, a 5–7 cm long incision just below and parallel to the clavicle was made from the mid-clavicular line to the axillary line. The subclavian artery was isolated by use of two rubber vascular loops passed around its proximal and distal portions and clamped at both ends. Heparin was administered to an activated clotting time (ACT) of <250 sec. A large 18–20 Fr Cook introducer sheath was amputated (10–12 cm length) and connected with the subclavian artery by means of a 15 cm x 8 mm Gelweave^{TM} polyester vascular prosthesis (Vascutek-Terumo, UK) using a so-called "chimney" approach, i.e., the vascular graft was anastomosed (end-to-side) onto a lateral incision on the subclavian artery (at the distal end) and the 10–12 cm long introducer sheath was inserted into the vascular prosthesis and sealed to it by a 2–0 silk suture (at the proximal end). In this way, the introducer sheath did not extend into the subclavian artery and the TAVR device could be inserted and advanced "sheathless" through the subclavian artery. Once the TAVR device was implanted, the graft was clamped with vascular staple clips just above the anastomosis with the subclavian artery, avoiding additional manipulation of the vessel. Following hemostasis, routine surgical wound closure was obtained with an intradermic suture.

From January 2019, all alternative TAVR procedures using the upper limb were performed by using a percutaneous transaxillary approach – no longer using surgical cut-down to the subclavian artery but by making use of two pre-closure suture-based ProGlide devices. Figure 2 illustrates our step-by

Year	Transfemoral (TF)	Shockwave -assisted TF	T-Subclavian/ T-Axillary	T-Aortic	T-Apical	T-Caval	Total TAVR	Non-TF access
2008	28	-	-	-	-	-	28	-
2009	42	-	-	-	-	-	42	-
2010	75	-	5	-	-	-	80	5 (6.3%)
2011	85	-	6	-	-	-	91	6 (6.6%)
2012	125	-	6	3	-	-	134	9 (6.7%)
2013	114	-	7	1	-	-	122	8 (6.6%)
2014	118	-	7	1	-	-	126	8 (6.3%)
2015	183	-	7	-	6	-	196	13 (6.6%)
2016	246	-	9	-	5	2	262	16 (6.1%)
2017	283	-	9	-	3	9	304	21 (6.9%)
2018	263	2	8	-	6	6	285	20 (7.0%)
2019	281	9	12	-	-	4	306	16 (5.2%)
Sept-2020	288	11	12	-	1	1	313	14 (4.5%)

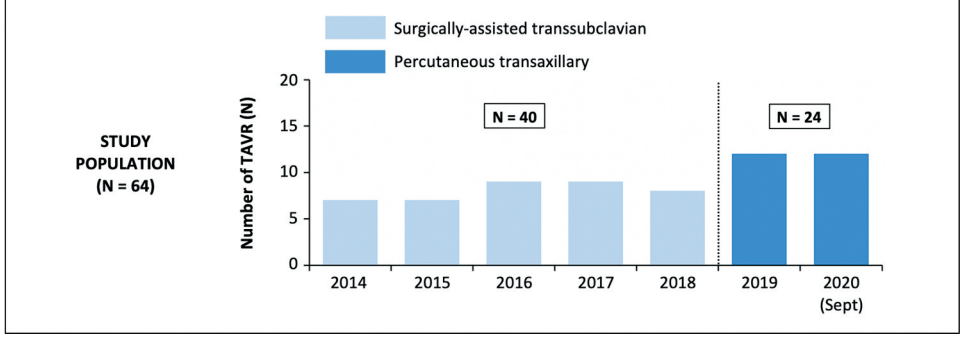

Figure 1. Local TAVR experience between January 2008 and September 2020, including the surgically-assisted transsubclavian and percutaneous transaxillary TAVR study population. TF, transfemoral; TAVR, transcatheter aortic valve replacement.

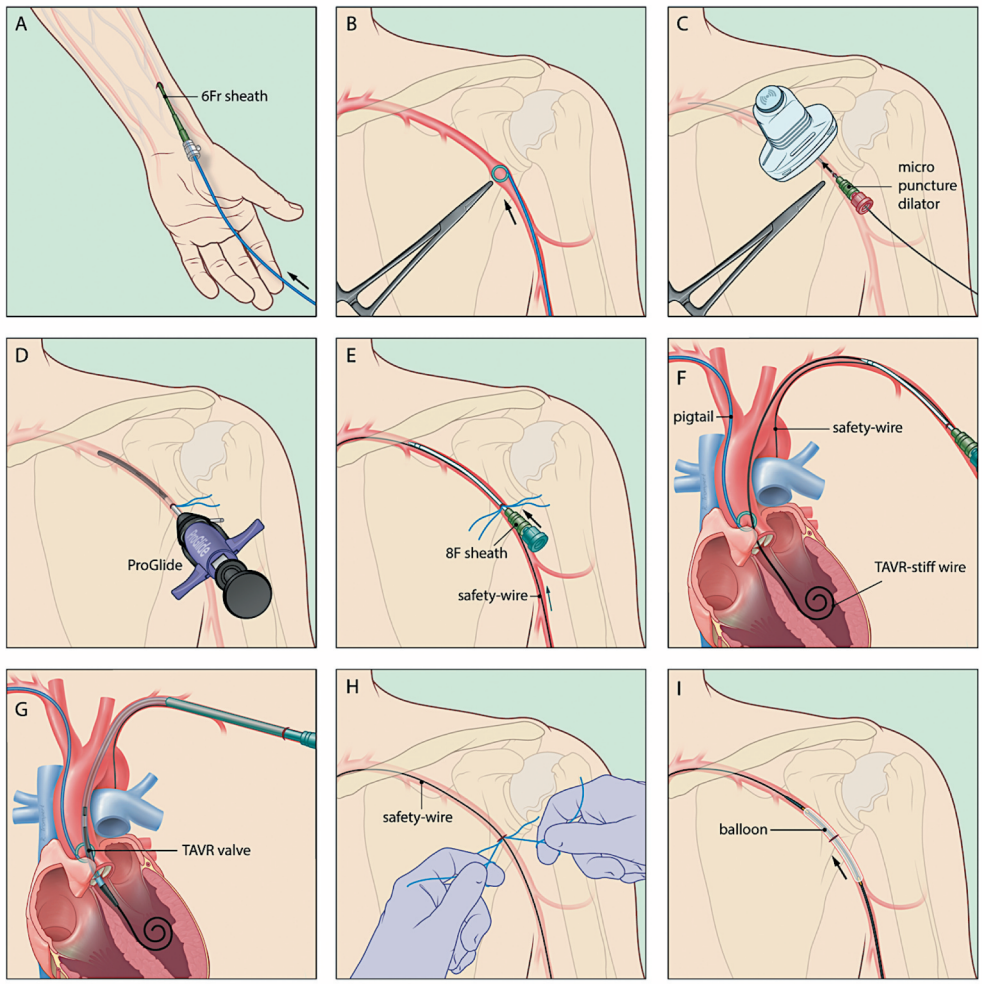

Figure 2. Percutaneous transaxillary TAVR – step-by-step description. (A) Placement of a 6 Fr sheath by the left radial artery, followed by insertion of a pigtail catheter. (B) The TAVR access site at the axillary artery is just medial of the caput humerus. A forceps and/or pigtail catheter can be used as fluoroscopic references. (C) The axillary artery is punctured under ultrasound and fluoroscopic guidance with the Micropuncture® access kit (Cook Medical, USA). (D) Axillary vessel preclosure was secured by means of two ProGlides® (Abbott, USA). (E) Following the ProGlide deployment, a 8 Fr sheath is inserted and a Platinum Plus™ (Boston Scientific, USA) safety wire is introduced from the left radial access – this safery wire is typically introduced further to the descending aorta. (F) The aortic valve is crossed and a TAVR safety wire is introduced into the left ventricle. A pigtail for contrast injection into the aortic root can be introduced by the right radial artery or a femoral artery – the latter in case of use of a Sentinel cerebral protection system (Boston Scientific, USA) using the right radial artery. (G) Next, the large-bore TAVR introduction sheath is inserted by the axillary access – typically only for the straight part of the subclavian artery – and TAVR is performed. (H) Finally, the TAVR system is removed and the stiff wire is exchanged for a 0.035" J-wire. Following removal of the introducer sheath, the access site is closed by use of the ProGlides and, in most of the cases, an additional 6 Fr AngioSeal® (Abbott, USA) device. (I) In case of incomplete vascular closure, retrograde delivery of a PTA balloon or a sheathless 8 mm COVERA® vascular stent graft (Bard, USA) over the safety wire is possible.

-step approach for percutaneous transaxillary TAVR. Transaxillary TAVR was planned as a minimally invasive procedure with arterial access from upper limbs only, or limited to a 6 F arterial femoral access (for insertion of a pigtail catheter) in case the right radial artery was used for a Sentinel cerebral embolic protection device (Boston Scientific, MN, USA). After insertion of the Sentinel device or TAVR introducer sheath, heparin was administered to an ACT < 250 sec. Patients were planned for early mobilization at 3 hours post-procedure. In order to optimize patient comfort and for operator ease, all procedures were performed under general anesthesia.

For all patients without an indication for oral anticoagulation (OAC), dual antiplatelet therapy was prescribed for three months, with long-term aspirin thereafter. Those with an indication for OAC were typically treated with OAC plus aspirin or clopidogrel. Since January 2020, this post-TAVR anti-thrombotic regimen has been changed to aspirin monotherapy for patients without an indication for OAC and OAC monotherapy for those with an indication for OAC therapy. Antiplatelets are pre-loaded before TAVR – if the patient is not on antiplatelet therapy yet – whereas OAC therapy is typically paused 3 days (OAC) or 1 day (NOAC) before TAVR and restarted one day after TAVR.

Statistics

Descriptive statistics were expressed as mean ± standard deviation for continuous variables and as frequency and percentages (%) for discrete variables. The differences in means between groups were determined using a Student's t-test or Wilcoxon rank-sum test, whereas a Chi-square test was used to test for associations between discrete variables. A two-tailed p-value <0.05 was considered to indicate statistical significance. For the comparison of 30-day outcomes, unadjusted 95% confidence intervals for the differences

in proportions between the two treatment groups are reported; these unadjusted intervals cannot be used to infer effects. Statistical analyses were performed using SPSS v24.0 software (IBM, USA).

Results

Study population

Being a center using the CoreValve™ TAVR system (Medtronic, MN, USA) only in the initial years of the TAVR program, it was a logical choice to have the first alternative access TAVR cases performed by transsubclavian approach. Different alternative accesses have been utilized to perform TAVR over the past decade (Figure 1). Use of alternative access was typically needed in 4% to 7% of our TAVR cases – in 2019, alternative access was utilized in 5.2% of all TAVR cases.

In total, 88 patients were treated by transsubclavian/axillary TAVR at our center – on a total of 2289 TAVR until September 2020 (3.8%). Between January 2014 and September 2020, a total of 64 patients were treated by transsubclavian/axillary TAVR – these patients were included in this study analysis. Forty patients underwent surgically assisted transsubclavian TAVR and 24 patients were treated by percutaneous transaxillary TAVR (Figure 1).

Demographic and baseline data

The baseline characteristics of the study population are reported in Table 1, dichotomized by procedural approach. Baseline characteristics were not statistically significant differences between both treatment groups. The mean age of the entire study population was 80 ± 7 years and 44% were female. Seven patients had prior coronary artery bypass grafting (CABG) with a LIMA to LAD. Mean calculated STS surgical risk was 3.2% ± 1.9% for the entire study population (Table 1).

Procedural characteristics and outcomes

A majority of patients were treated because of severe, tricuspid aortic valve stenosis; one patient had a bicuspid aortic stenosis and one other patient a stenotic surgical aortic bioprosthesis. All but one patient was treated with self-expanding transcatheter heart valves (Table 2). A cerebral embolic protection system was used in 16 patients of the percutaneous transaxillary group. Hospitalization length was significantly shorter for patients treated by percutaneous vs. surgical approach (1.2 vs. 4.4 days; p <0.001). Twenty patients (83%) treated by percutaneous transaxillary TAVR had a next-day hospital discharge vs. none of the patients following surgically assisted TAVR.

30-day outcomes

Except for one patient presenting with a non-disabling stroke and one patient with acute kidney injury grade 2, no other patients in the percutaneous transaxillary TAVR group encountered a VARC-2-defined safety outcome event. Only one patient treated by percutaneous transaxillary approach was rehospitalized within 30 days, despite being discharged early after TAVR (Table 3).

In the surgically assisted transsubclavian TAVR group, the combined safety endpoint at 30 days was reached in 29 out of 40 patients (73% vs. 92% in the percutaneous group; Table 3). Six patients were reported to have a major vascular complication: (a) one patient with a dissection of the subclavian artery involving the LIMA bypass graft, needing stenting of the subclavian artery and ostial LIMA; (b) one patient with left ventricular wire perforation and life-threatening bleeding requiring emergency thoracotomy; (c) two patients with major access site bleeding and need for emergent stenting of the subclavian artery; and (d) two patients with permanent access site-related nerve injury. In addition, six patients were rehospitalized within 30 days after TAVR: (a) two patients with a growing hematoma at the access site after discharge, treated conservatively; (b) two patients with fever and increased infection parameters resulting in initiation of antibiotic therapy; (c) one patient because of pain and suspicion of neurologic dysfunction of the left upper limb; and (d) one patient with symptomatic complete heart block two days after discharge requiring pacemaker implantation.

Table 1. Demographic and baseline data.

	Surgical transsubclavian N = 40	Percutaneous transaxillary N = 24	p-Value
Baseline patient characteristics			
Age, years	80 ± 6	79 ± 7	0.691
Female	19 (48%)	9 (38%)	0.603
Arterial hypertension	33 (83%)	20 (83%)	1.000
Hyperlipidemia	28 (70%)	16 (67%)	1.000
Body Mass Index, kg/m^2	25 ± 7	26 ± 6	0.840
Diabetes mellitus	15 (38%)	6 (25%)	0.412
Previous myocardial infarction	8 (20%)	2 (8%)	0.297
Prior PCI	9 (23%)	6 (25%)	1.000
Prior CABG	6 (15%)	1 (4%)	0.241
Atrial fibrillation	11 (28%)	8 (33%)	0.778
Prior cerebrovascular event	6 (15%)	3 (13%)	1.000
GFR < 60 mL/min	15 (38%)	10 (42%)	0.795
Chronic lung disease	13 (33%)	5 (21%)	0.396
STS surgical risk score, %	3.4 ± 2.2	3.0 ± 1.2	0.671
Baseline echocardiographic data			
Left ventricular ejection fraction, %	49 ± 12	51 ± 10	0.545
Left ventricular ejection fraction < 30%	2 (5%)	1 (4%)	1.000
Mean AV gradient (mmHg)	40 ± 12	44 ± 16	0.419
Aortic valve area, cm^2	0.7 ± 0.2	0.7 ± 0.3	0.583
Aortic regurgitation ≥ moderate	1 (3%)	1 (4%)	1.000
Mitral regurgitation ≥ moderate	2 (5%)	2 (8%)	1.000

Notes. AV, aortic valve; CABG, coronary artery bypass grafting; GFR, glomerular filtration rate; PCI, percutaneous coronary intervention; STS, Society of Thoracic Surgeons.

Discussion

Percutaneous transfemoral access is the standard of care for patients undergoing TAVR. However, a significant portion of TAVR patients require alternative access which can increase hospital length-of-stay and can carry the additional, more

Table 2. Procedural and in-hospital data.

	Surgical transsubclavian N = 40	Percutaneous transaxillary N = 24	*P*-Value
Aortic valve disease			0.321
Tricuspid aortic valve	39 (97%)	23 (96%)	
Bicuspid aortic valve	1 (3%)	0	
Valve-in-valve	0	1 (4%)	
Valve type			0.134
CoreValve/Evolut	17 (43%)	5 (21%)	
Portico	22 (55%)	19 (79%)	
Sapien 3	1 (3%)	0	
Single valve implanted	37 (93%)	24 (100%)	0.286
Predilatation	28 (70%)	20 (83%)	0.372
Postdilatation	14 (35%)	3 (13%)	0.078
Cerebral protection system	0	16 (67%)	< 0.001
Fluoroscopy time, min	24 ± 6	27 ± 11	0.251
Contrast, mL	112 ± 40	108 ± 38	0.980
Procedural mortality	0	0	-
Permanent pacemaker implantation	4 (10%)	2 (8%)	1.000
Hospitalization length, days	4.4 ± 1.5	1.2 ± 0.8	< 0.001
Next-day discharge	0	20 (83%)	< 0.001

invasive aspect of a surgical access wound. A range of alternative access sites for TAVR exist – importantly, a truly percutaneous approach is possible via the transaxillary route. Transsubclavian/axillary TAVR has been shown to have good clinical outcome, comparable to transfemoral access.[8–10] Pooled analysis of more than 10,000 TAVR has recently shown mortality benefit with a transsubclavian/axillary approach for alternative access TAVR over transapical and direct aortic access.[11] In this study, we report the safety and efficacy of a standardized percutaneous transaxillary TAVR approach and made a comparison with our earlier surgically assisted transsubclavian TAVR experience.

To date, no studies have indicated an optimal time to discharge following percutaneous transaxillary TAVR. In a series of 100 percutaneous transaxillary TAVR cases, hospital length-of-stay was 7.9 ± 4.3 days[2] – however, this study was from Germany where early discharge is known to incur a financial penalty for the hospital. An Italian registry of 202 surgically assisted transsubclavian TAVR reported a hospitalization of 8.3 ± 6.5 days.[9] The application of a fast-track recovery and discharge protocol in a predominantly surgical transsubclavian TAVR cohort made no difference in hospitalization stay, bringing the median length-of-stay from 6 (range 4–6.5) to 5 (range 3–7) days ($p = 0.6$).[12]

Importantly, there was no significant difference in early safety between the two treatment cohorts in this study. A tendency toward fewer adverse events with the percutaneous approach warrants a larger study that can clarify the safest – and most efficient – form of vascular access at this site. Given the large and growing number of patients referred for TAVR, having an optimal pathway for alternative access TAVR, along with the option of early discharge, is increasingly important.

Using a standardized percutaneous approach to transaxillary TAVR, this study was also able to show the feasibility of next-day discharge as well as a significant reduction in hospital length-of-stay when compared to surgically assisted transsubclavian TAVR. Only 2 out of 24 patients (8%) remained hospitalized for ≥3 days after percutaneous transaxillary TAVR – one patient because of higher risk for conduction abnormalities (due to pre-existing right bundle branch block) but no change in PR or QRS intervals at 12-lead electrocardiogram (ECG) following TAVR and one other patient receiving a permanent pacemaker two days after TAVR because of third-degree AV block. In this way, we were able to apply our post-TAVR care program as for routine percutaneous transfemoral TAVR cases. In 2019, nearly 70% of all transfemoral TAVR cases treated at our institution were discharged home the day after TAVR.

Table 3. 30-day outcomes.

	Surgical transsubclavian N = 40	Percutaneous transaxillary N = 24	Difference in Proportions (95%CI)
Early safety at 30 days	29 (73%)	22 (92%)	19% (−2% to 36%)
All-cause mortality	0	0	-
All stroke	2 (5%)	1 (4%)	−1% (−13% to 2%)
Major vascular complications	6 (15%)	0	−15% (−29% to 1%)
Life-threatening bleeding	1 (3%)	0	−3% (−13% to 11%)
Acute kidney injury ≥ grade 2	7 (18%)	1 (4%)	−14% (−28% to 5%)
Myocardial infarction	0	0	-
Redo-intervention	0	0	-
Early clinical efficacy at 30 days	34 (85%)	22 (92%)	7% (−13% to 22%)
All-cause mortality	0	0	-
All stroke	2 (5%)	1 (4%)	−1% (−13% to 2%)
Valve dysfunction	2 (5%)	0	−5% (−17% to 9%)
Mean gradient ≥20 mmHg	0	0	-
Aortic regurgitation ≥ moderate	2 (5%)	0	−5% (−17% to 9%)
NYHA ≥ class 3	3 (8%)	1 (4%)	−4% (−16% to 13%)
Rehospitalisation at 30 days	6 (15%)	1 (4%)	−11% (−25% to 7%)

*Notes.*NYHA, New York Heart Association.

Percutaneous vascular closure is a reliable approach to manage the post-TAVR access site; however, concerns remain when considering using percutaneous vascular closure techniques at non-compressible locations such as the axillary artery. For this reason, percutaneous transaxillary TAVR must be performed with reliable access to bail-out percutaneous transluminal angioplasty (PTA) and covered stent delivery. The approach illustrated in Figure 2 maximizes use of upper limb arterial access in order to promote early mobilization and maintains a safety wire across the access site throughout the entire TAVR procedure, offering a bail-out option in case of a vascular complication. This approach proved to be safe, with no vascular complications noted in this study albeit with small numbers.

Limitations

This study is subject to the usual pitfalls of a single center, partially retrospective (for the surgical cohort) study. The limited sample size and statistical power of this study do not allow testing for superiority or non-inferiority between both treatment strategies. There was no independent adjudication of safety and efficacy outcomes. Although a next-day discharge pathway for TAVR cases has been in place at our institution since 2014, we recognize that this policy has only been adopted systematically since 2017 – this may have introduced bias concerning the hospital length-of-stay of the transsubclavian cases treated in the period 2014 to 2016. Nevertheless, this study recruited all consecutive patients treated by transsubclavian/axillary access at our institution and has no missing variables or data at follow-up, owing to the unique Danish patient identification system.

Conclusions

The adoption of a standardized percutaneous transaxillary TAVR approach resulted in a significantly shorter hospitalization without any difference in safety as compared to a surgically assisted transsubclavian TAVR approach. Next-day discharge following percutaneous transaxillary TAVR appears to be feasible and safe. There is a need for safe and efficient care pathways for patients needing alternative access to TAVR, similar to transfemoral TAVR. In this setting, percutaneous transaxillary TAVR warrants further investigation in a larger study population.

ORCID

Ben Wilkins http://orcid.org/0000-0002-4771-9157

Funding

Ben Wilkins is supported by the New Zealand Heart Foundation Training and Research Fellowship [Grant # 1778].

Disclosure statement

No potential conflict of interest was reported by the authors.

References

1. Wood DA, Lauck SB, Cairns JA, et al. The vancouver 3M (multidisciplinary, multimodality, but minimalist) clinical pathway facilitates safe next-day discharge home at low-, medium-, and high-volume transfemoral transcatheter aortic valve replacement centers: the 3M TAVR study. *JACC: Cardiovascular Interventions*. 2019;12(5):459–469. doi:10.1016/j.jcin.2018.12.020.
2. Schafer U, Deuschl F, Schofer N, et al. Safety and efficacy of the percutaneous transaxillary access for transcatheter aortic valve implantation using various transcatheter heart valves in 100 consecutive patients. *Int J Cardiol*. 2017;232:247–254. doi:10.1016/j.ijcard.2017.01.010.
3. Carroll JD, Vemulapalli S, Dai D, et al. Procedural experience for transcatheter aortic valve replacement and relation to outcomes: the STS/ACC TVT registry. *J Am Coll Cardiol*. 2017;70(1):29–41. doi:10.1016/j.jacc.2017.04.056.
4. Nakamura M, Chakravarty T, Jilaihawi H, et al. Complete percutaneous approach for arterial access in transfemoral transcatheter aortic valve replacement: a comparison with surgical cut-down and closure. *Catheter Cardiovasc Interv*. 2014;84(2):293–300. doi:10.1002/ccd.25130.
5. Arbel Y, Zivkovic N, Mehta D, et al. Factors associated with length of stay following trans-catheter aortic valve replacement - a multicenter study. *BMC Cardiovasc Disord*. 2017;17(1):137. doi:10.1186/s12872-017-0573-7.
6. Costa G, Bieliauskas G, Fukutomi M, Ihlemann N, Søndergaard L, De Backer O. Feasibility and safety of a fully percutaneous transcatheter aortic valve replacement program. *Catheter Cardiovasc Interv*. 2020. doi:10.1002/ccd.29117.
7. Biasco L, De Backer O, Holme S, Sondergaard L, The JA. "Chimney approach" for transcatheter aortic valve implantation: a strategy for trans axillarian bareback approach in patients with no other access options. *Catheter Cardiovasc Interv*. 2015;86:E167–73. doi:10.1002/ccd.25840.
8. Schofer N, Deuschl F, Conradi L, et al. Preferential short cut or alternative route: the transaxillary access for transcatheter aortic valve implantation. *J Thorac Dis*. 2015;7:1543–1547.
9. Petronio AS, De Carlo M, Bedogni F, et al. 2-year results of core valve implantation through the subclavian access: a propensity-matched comparison with the femoral access. *J Am Coll Cardiol*. 2012;60(6):502–507. doi:10.1016/j.jacc.2012.04.014.
10. Gleason TG, Schindler JT, Hagberg RC, et al. Subclavian/axillary access for self-expanding transcatheter aortic valve replacement renders equivalent outcomes as transfemoral. *Ann Thorac Surg*. 2018;105(2):477–483. doi:10.1016/j.athoracsur.2017.07.017.
11. Takagi H, Hari Y, Nakashima K, Kuno T, Ando T. Comparison of early and midterm outcomes after transsubclavian/axillary versus transfemoral, transapical, or transaortic transcatheter aortic valve implantation. Heart & lung. 2019;48(6):519–529.doi:10.1016/j.hrtlng.2019.04.002.
12. Kolkailah AA, Hirji SA, Ejiofor JI, et al. Novel fast-track recovery protocol for alternative access transcatheter aortic valve replacement: application to non-femoral approaches. *Interact Cardiovasc Thorac Surg*. 2018;26(6):938–943. doi:10.1093/icvts/ivx409.