Title

Transcarotid versus transthoracic transcatheter aortic valve replacement: A systematic review and meta-analysis

Authors

Munguti, Cyrus
Ndunda, Paul
Vindhyal, Mohinder R
et al.

Publication Date

2024

DOI

10.1016/j.carrev.2024.01.015

Peer reviewed

Cardiovascular Revascularization Medicine xxx (xxxx) xxx

Contents lists available at ScienceDirect

Cardiovascular Revascularization Medicine

journal homepage: www.sciencedirect.com/journal/cardiovascular-revascularization-medicine

Transcarotid versus transthoracic transcatheter aortic valve replacement: A systematic review and meta-analysis

Cyrus Munguti [a], Paul Ndunda [a], Mohinder R. Vindhyal [a], Abdullah Abukar [c], Mohammed Abdel-Jawad [a,b], Zaher Fanari [d,*]

[a] Internal Medicine, University of Kansas School of Medicine – Wichita, KS, United States of America
[b] Internal Medicine, Ascension Via Christi St Francis Hospital, Wichita, KS, United States of America
[c] Internal Medicine, University of California San Francisco, San Francisco, CA, United States of America
[d] Internal Medicine/Cardiology, University of California San Francisco, Fresno, CA, United States of America

ARTICLE INFO

Keywords:
Transcarotid
Transthoracic Transcatheter aortic valve replacement
Transaortic

ABSTRACT

Background: Transthoracic approaches may be contraindicated in some patients and may be associated with poorer outcomes. Therefore other alternative access routes are increasingly being performed. We conducted a systematic review of the literature on Transcarotid transcatheter aortic valve replacement (TC-TAVR) and meta-analysis comparing outcomes of TC-TAVR and other access routes.
Methods: We comprehensively searched for controlled randomized and non-randomized studies from 4 online databases. We presented data using risk ratios (95 % confidence intervals) and measured heterogeneity using Higgins' I^2.
Results: Sixteen observational studies on Transcarotid TAVR were included in the analysis; 4 studies compared 180 TC-TAVR patients vs 524 TT-TAVR patients. The mean age and STS score for patients undergoing TC-TAVR were 80 years and 7.6 respectively. For TT-TAVR patients, the mean age and STS score were 79.7 years and 8.7 respectively. TC-TAVR patients had lower 30-day MACE [7.8 % vs 13.7 %; OR 0.54 (95 % CI 0.29–0.99, $P = 0.05$)] and major or life-threatening bleeding [4.0 % vs 14.2 %; OR 0.25 (95 % CI 0.09–0.67, $P = 0.006$)]. There was no significant difference in 30-day: mortality [5.0 % vs 8.6 %; OR 0.61 (95 % CI 0.29–1.30, $P = 0.20$)], stroke or transient ischemic attack [2.8 % vs 4.0 %; OR 0.65 (95 % CI 0.25–1.73, $P = 0.39$)] and moderate or severe aortic valve regurgitation [5.0 % vs 4.6 %; OR 1.14. (95 % CI 0.52–2.52, $P = 0.75$)]. There was a trend towards fewer major vascular complications in TC-TAVR [3.0 % vs 7.8 %; OR 0.42 (95 % CI 0.16–1.12, $P = 0.08$)].
Conclusion: Compared with transthoracic TAVR, TC-TAVR patients had lower odds of 30-day MACE and life-threatening bleeding and no differences in 30-day mortality, stroke or TIA, aortic valve regurgitation.

1. Introduction

A total of 72,991transcatheter aortic valve replacement procedures were performed in 2019 in the United States, that number is increasing every year and consistently surpassing the annual volume of surgical aortic valve replacement [1]. Since the incidence of aortic stenosis and cardiac surgical risk increase with age, this number is likely to rise as the population ages [2]. Besides, as transcatheter aortic valve replacement is adopted among lower-risk patients, the number of procedures is likely to grow even further [3].

Guidelines recommend transfemoral access during TAVR as the first choice due to its extensive use in clinical trials, minimal invasiveness, ability to be done under sedation, and safety [4]. In the initial TAVR studies, up to 25–30 % of patients were precluded from transfemoral access. Due to an improvement in technology the transcatheter heart valves can be delivered in catheters as small as 14F [5]. This has led to a further decrease in the proportion of patients that need alternative vascular access.

The main contraindications to transfemoral TAVR include unsuitable femoral/iliac artery or aortic size, tortuosity, or anatomy [1]. Alternative access sites that have been studied for TAVR include the transapical, transaortic, Transcarotid, transcaval, transaxillary/subclavian and transeptal routes [1]. In the 2021 annual report of the Society of Thoracic Surgeons/American College of Cardiology Transcatheter Valve Therapy (TVT) registry, 8.99 % of patients underwent TAVR via access sites other than the femoral artery [1]. Of these 8.99 % alternative access reported transthoracic access was surprisingly still widely dominant with 5.88 % of cases reported (transapical was 4.11 % and Transaortic 1.77 %). Non transthoracic accesses reported were subclavian 1.88 %, axillary 0.83 %, transcarotid 0.53 %, transeptal 0.01 % and transcaval 0.04 % [1].

While the most commonly used alternative approaches in the US in the 2021 have been transapical and transaortic, these approaches are invasive, require general anesthesia and may not be feasible in some patients with previous thoracic or cardiac surgery [1]. Also, some studies suggest a high morbidity with these routes and higher mortality with transapical access and therefore, there is a need for further research on alternative access for TAVR [6].

Studies on Transcarotid access for TAVR have reported variable findings and had small sample sizes [7–19]. With the recent publication of several

* Corresponding author at: Internal Medicine/Cardiology, University of California San Francisco, 2335 E Kashian Ln, Suite 460, Fresno, CA 93701, United States of America.

http://dx.doi.org/10.1016/j.carrev.2024.01.015
Received 27 June 2023; Received in revised form 27 December 2023; Accepted 23 January 2024
Available online xxxx

controlled observational studies, we performed a systematic review and meta-analysis of observational studies to assess the clinical outcomes of Transcarotid approach compared with transthoracic (transapical and transaortic) approaches.

2. Methods

We followed the QUOROM (The Quality of Reporting of Meta-analyses) and PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines throughout the process of performing and reporting this study [20,21].

2.1. Search strategy

We searched MEDLINE, Cochrane Library, the Web of Science and Google Scholar, for relevant publications since inception until November 25, 2018. We used various combinations of Medical Subject Heading (MeSH) terms and keywords representing the following concepts: "transcatheter aortic valve replacement," "Transcarotid," "transaortic" and "transapical." We also searched ClinicalTrials.gov (November 25, 2018) for clinical trials. We reviewed references of the full-text articles that we retrieved for more studies.

2.2. Study selection

Two investigators (C.M and P.N) independently screened the search results and assessed study eligibility. We resolved differences by consensus, and where we could not reach an agreement, a third author (Z.F.) made the decision.

The study inclusion criteria were:

1. Randomized controlled trials (RCTs) or controlled observational studies that compared the outcomes of Transcarotid TAVR with transaortic or transapical TAVR.
2. Studies that reported clinical or aortic valve area and hemodynamic outcomes

Exclusion criteria were:

1. Studies that were not published in English and English translation could not be obtained
2. Case reports

A PRISMA flow diagram summarizing literature search and selection of studies is shown in Fig. 1.

2.3. Data extraction and study quality assessment

The two authors (CM and PN) independently reviewed the included studies and summarized the study characteristics in a data extraction table. The data collected were author, year of publication, number of patients, study design, TAVR access routes, type of transcatheter heart valve, valve size, type of anesthesia, side of carotid artery access (right or left), use of balloon aortic valvuloplasty, use of a carotid shunt, cerebral perfusion monitoring, patient demographic, and clinical characteristics. The following outcomes were collected: 30-day major adverse cardiovascular events (MACE) (mortality, stroke or transient ischemic attack), mortality, stroke, transient ischemic attack (TIA), bleeding and major vascular complications. We assessed the study risk of bias using the Cochrane

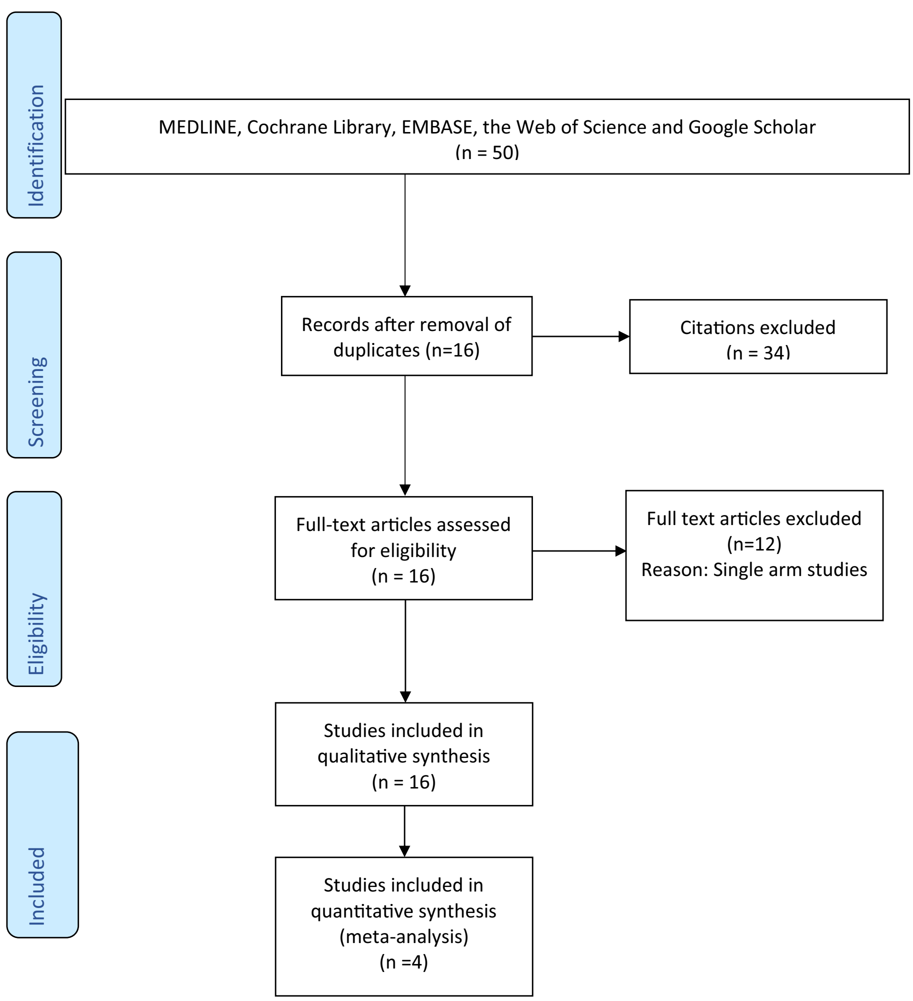

Fig. 1. PRISMA flow diagram of studies included in data search.

Table 1
Characteristics of studies included in systematic review and meta-analysis.

Study/author, Yr	Study type	Full-text publication?	Request full text from	TC vs TA	TC vs TAo
Kirker, 2017	Controlled observ	Yes	No	X	
Thourani, 2015	Controlled observ	Yes	No	X	X
Damluji, 2018	Controlled Observ	Yes	No	X	X
Chamadi, 2018	Controlled Observ	No	Library	X	X

Collaboration's tool: Risk of Bias in Non-randomized Studies - of Interventions (ROBINS-I tool) [22].

2.4. Statistical analysis

Seven controlled observational studies were included in the meta-analysis. Risk ratios (RR) and 95 % confidence intervals (95 % CI) were used to report effect sizes, and the Higgin's I-squared (I^2) statistic was used to measure statistical heterogeneity. We used a fixed effects model in analyses with heterogeneity of ≤25 %. A significance level of 0.05 was used for all analyses. We performed sensitivity analyses by removing one study at a time. We used Cochrane's RevMan 5.3 for meta-analysis. We did not create a funnel plot because of the small number of controlled studies. Among the controlled studies, data were quite homogeneous; therefore we performed a meta-analysis.

3. Results

3.1. Search results and study characteristics

Of sixteen observational studies only four reported outcomes comparing transcarotid with transaortic TAVR. The total number of patients in the included studies was 180 patients in the transcarotid arm compared with 524 patients in the transthoracic arm. Table 1 summarizes the characteristics of studies included in the systematic review and meta-analysis.

3.2. Patient characteristics

All patients had a contraindication to transfemoral access. However, different centers used different algorithms in patients that had a contraindication to transfemoral access. The transcarotid route was considered if patients were not candidates for transfemoral, transapical and transaortic access. In three studies, it was considered a second option after transfemoral access.

The mean age for all patients undergoing TC-TAVR was 80 years, and 53.1 % were males. The mean STS score was 7.6. Three studies reported only EUROSCORE II and the mean was 9.1. Seventy percent and 18.2 % of patients undergoing TC-TAVR had a history of peripheral artery disease of and myocardial infarction respectively. The mean aortic valve area was 0.78 cm^{2,} and the mean transaortic valve gradient was 58.8 mmHg.

Among patients undergoing transthoracic TAVR, the mean age was 79.7 years, and 55.7 % of the cohort was male. The mean STS score was 8.7. Peripheral artery disease and myocardial infarction were present in

Table 2
Patient characteristics.

Study author, yr	Number OF patients transcarotid vs transthoracic	Age	Male gender (%)	STS risk	Logistic euroscore	Euroscore II	NYHA class III/IV	H/O stroke	H/O DM
Chamadi, 2018	101 VS 228	80.4 ± 8.4	55 (54.5)	6.6 ± 5.7		8.7 ± 7.5		16 (15.8)	42 (41.6)
Damluji, 2018*	43 VS 112	81 (72–86)	27 (63)	6.9 (4.1–8.7)			27 (63)	3 (7)	17 (40)
Kirker, 2017*	25 VS 112	77.0 (72.0–83.0)	13 (52.0)	6.1 (4.1–9.6)			10 (40.0)	12 (48.0)	12 (48.0)
Thourani, 2015	11 VS 172	68.9 ± 23.6	5 (45.4)	17.1 ± 8.8			10 (90.9)	1 (9.1)	4 (36.4)

Study author, yr	H/O hypertension	H/O CABG	H/O PCI	H/O PAD	Creatinine	ON dialysis	A FIB	MI	LVEF	Aortic valve area	Mean AV gradient
Chamadi, 2018	82 (81.2)	24 (23.8)		67 (66.3)			41 (40.6)	20 (19.8)	55 ± 12	0.66 ± 0.15	51 ± 13
Damluji, 2018*	34 (79)				1.3 (0.9–1.80)		16 (37)	15 (35)	55 (35–60)	0.7 (0.5–0.9)	44 (35–53)
Kirker, 2017*	22 (88.0)	9 (36.0)		20 (80.0)	1.20 (1.06–1.58)	2 (8.0)			55 (35–60)	0.7 (0.52–0.79)	32 (27.5–39.25)
Thourani, 2015	9 (81.8)	6 (54.6)		8 (72.7)	1.72 ± 0.95	0 (0.0)		2 (18.2)	45.5 ± 17.4	0.62 ± 0.17	42.0 ± 18.1

Table 3
Procedural data for transcarotid TAVR.

Study author, yr	Valve type (TC-TAVR)	Valve size (TC-TAVR) (mm)	Anethesia for TC-TAVR	Carotid artery access	Shunt	Cerebral O2 saturation monitoring	BAV	Reason TC chosen	TC access exclusion criteria
Chamadi, 2018	Sapien 3–49.5 % Evolut R - 34.7 % CoreValve - 7.9 % Sapien XT - 7.9 %		GA - 100 %	Left - 97 %	yes - Only when indicated	yes	in 38.5 % cases		Common carotid artery (CCA) lumen diameter < 7 mm, Contralateral carotid artery occlusion, significant (≥50 %) internal or CCA stenosis, and occlusion or stenosis of vertebral arteries
Damluji, 2018	CoreValve - 49 % Sapien 3–12 % Sapien XT - 10 %	All Valves - 26.8	GA - 100 %	No data	No	No	Yes	Not clear	
Kirker, 2017	Sapien 3–56 % Sapien XT - 28 % CoreValve 3–12% Sapien - 4 %	Sapien, Sapien XT/3–25.9 Corevalve - 26.5	GA - 100 %	Right - 85 %	No	Yes	Yes		Carotid diameter <6.5 mm, >50 % contralateral carotid stenosis, vertebral artery stenosis with contralateral vertebral retrograde flow consistent with steal at rest
Thourani, 2015	Sapien - 100 %	23–26	GA - 100 %	Right - 100 %	Yes	Yes	Yes	Not candidate for TF, TA0 & TA.	

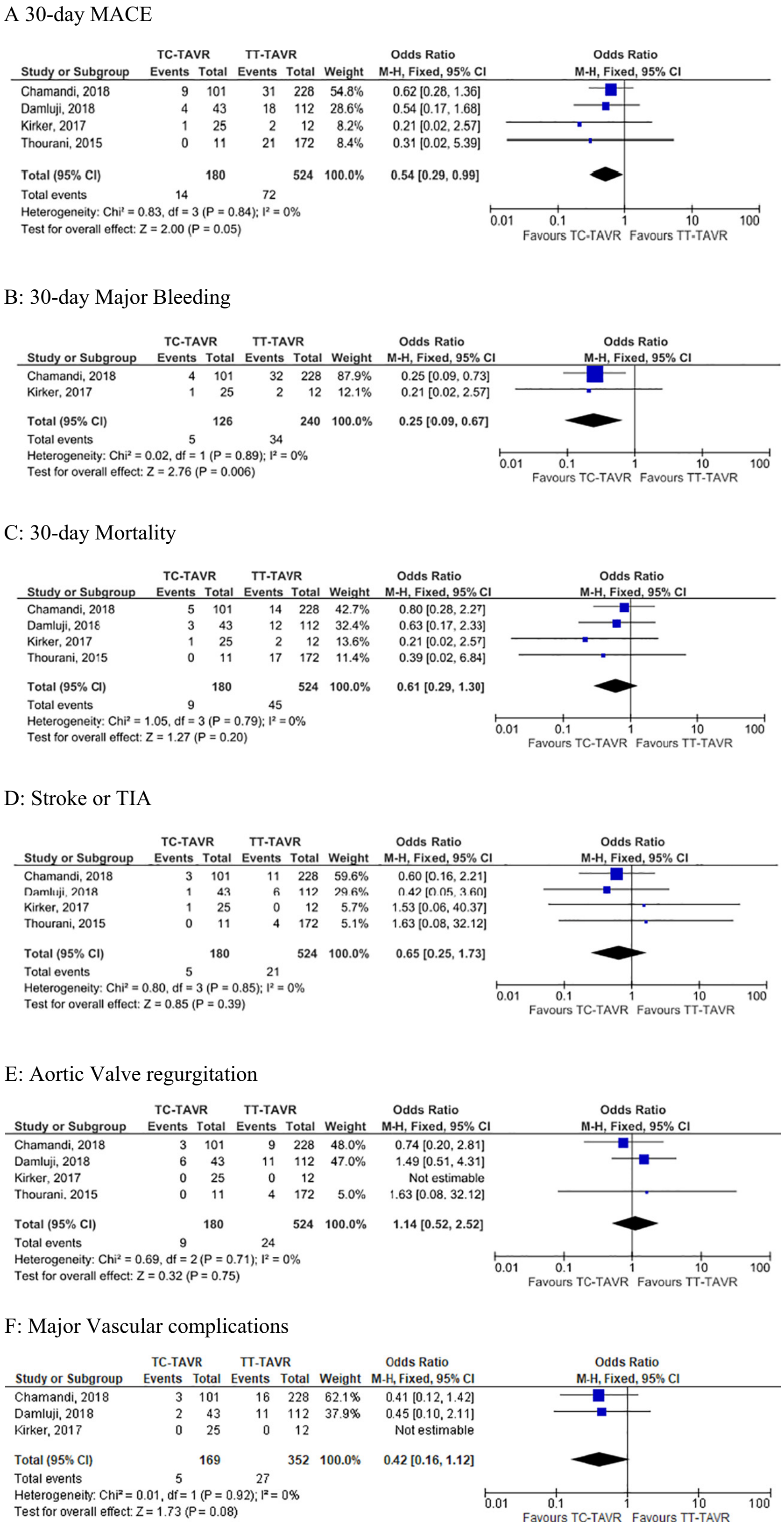

Fig. 2. Outcomes of transcarotid versus transthoracic transcathter aortic valve replacement. A 30-day MACE. B: 30-day major bleeding. C: 30-day mortality. D: Stroke or TIA. E: Aortic valve regurgitation. F: Major vascular complications.

52 % and 36.2 % respectively. The echocardiographic characteristics were as follows: mean aortic valve area of 0.7 cm^2, mean transaortic valve gradient of 40.7 mmHg and mean left ventricular ejection fraction of 51.2 %.

Table 2 summarizes the patient demographic and clinical characteristics of the different studies.

3.3. Transcarotid TAVR procedural methods

Among patients undergoing transcarotid TAVR, the types of valves used were as follows: Sapien – 11.3 %, SAPIEN XT – 9.6 %, SAPIEN 3–13.3 %, Medtronic CoreValve – 59.2 % and Evolut R – 6.4 % General anesthesia was used in 91 % of all TC-TAVR procedures.

Table 3 summarizes the methods and materials used in the transcarotid TAVR procedure.

3.4. Outcomes

3.4.1. Transcarotid vs. transthoracic TAVR

Compared with transthoracic TAVR, TC-TAVR patients had lower odds of 30-day MACE [7.8 % vs 13.7 %; OR 0.54 (95 % CI 0.29–0.99, $P = 0.05$) $I^2 = 0$ %, Fig. 2A] and major or life-threatening bleeding [4.0 % vs 14.2 %; OR 0.25 (95 % CI 0.09–0.67, $P = 0.006$) $I^2 = 0$ %, Fig. 2B]. There was no significant difference in 30-day: mortality [5.0 % vs 8.6 %; OR 0.61 (95 % CI 0.29–1.30, $P = 0.20$) $I^2 = 0$ %, Fig. 2C], stroke or transient ischemic attack [2.8 % vs 4.0 %; OR 0.65 (95 % CI 0.25–1.73, $P = 0.39$) $I^2 = 0$ %, Fig. 2D] and moderate or severe aortic valve regurgitation [5.0 % vs 4.6 %; OR 1.14. (95 % CI 0.52–2.52, $P = 0.75$) $I^2 = 0$ %, Fig. 2E]. There was a trend towards fewer major vascular complications in TC-TAVR compared with TT-TAVR [3.0 % vs 7.8 %; OR 0.42 (95 % CI 0.16–1.12, $P = 0.08$) $I^2 = 0$ %, Fig. 2F].

4. Discussion

Our meta-analysis was done on four studies with outcomes of interest. Compared with transthoracic TAVR, TC-TAVR patients had lower odds of 30-day MACE and major or life-threatening bleeding. There was no significant difference in the odds of mortality, stroke, major vascular complications, and moderate or severe aortic valve regurgitation.

A higher proportion of patients undergoing TC-TAVR had a history of PAD but lower proportion with myocardial infarction and their STS scores were lower than in transthoracic TAVR. One of the major concerns about TC-TAVR is the risk of stroke. However, in this analysis, the odds of stroke among the TC-TAVR group were not significantly different from the control group. Most studies did a cross-clamp test and cerebral oxygen saturation monitoring during the procedure and used a carotid shunt when these two tests were abnormal. These procedures might have mitigated the risk of stroke. However, there may be other reasons why the risk of stroke in TC-TAVR is not higher than in TT-TAVR. The carotid artery occlusion is not complete during TAVR since blood flows anterograde around the sheath [11]. Also, retrograde flow from the external carotid artery into the internal carotid artery via the segment of the common carotid artery that is intact may maintain cerebral circulation. [8] Finally, the mid-segment of the common carotid artery that is usually used for access in TC-TAVR usually doesn't have atherosclerosis [8]. The initial risk of stroke among TC-TAVR patients was relatively high, ranging from 5.7 % to 7 % [11,13]. This risk has declined in recent studies due to the use of smaller delivery catheters. [23]. Some recent studies have also used local anesthesia which might reduce hypotensive episodes and consequently watershed stroke events [7,11,24].

The outcomes following the use of alternative access sites in TAVR have been variable between studies [25]. According to the STS/ACC TVT registry 2021 data, 4,4 % of TAVR procedures were done through the transapical route which is decline when compared to the 2016 data because it is more invasive and high-risk leading to higher morbidity and mortality [1,26]. this higher morbidity and mortality can be explained by its higher rate of complications include major bleeding, accidental coronary artery injury, ventricular apex aneurysm, arrhythmias, and acute kidney injury [25,27–30]. Transaortic access is also invasive and may not be feasible in patients with a history of a sternotomy, chest radiation therapy or patients with coronary artery bypass grafts that overlie the aorta [25]. The higher MACE, major or life-threatening bleeding and major vascular complications with transthoracic TAVR compared with TC-TAVR in this analysis, show a similar pattern to previous studies comparing transthoracic TAVR with TF-TAVR [31–33].

Transaxillary and subclavian access may be contraindicated in some patients with arterial tortuosity, calcification, and coronary artery bypass graft (CABG) with a patent left internal mammary artery (which can lead to myocardial hypoperfusion during Transaxillary TAVR) [13].

Whether right or left carotid approach leads to better outcomes remains unclear and requires further study.

5. Conclusion

This meta-analysis suggests that there are no significant differences in mortality, stroke MACE and major or life-threatening bleeding or vascular complications when TC-TAVR is compared to TF-TAVR approaches. However, compared with transthoracic TAVR, TC-TAVR patients had lower odds of 30-day MACE and major or life-threatening bleeding.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Cyrus Munguti: Conceptualization, Formal analysis, Writing – original draft. **Paul Ndunda:** Formal analysis, Writing – review & editing. **Mohinder R. Vindhyal:** Data curation, Writing – review & editing. **Abdullah Abukar:** Conceptualization, Data curation, Writing – review & editing. **Mohammed Abdel-Jawad:** Data curation, Writing – review & editing. **Zaher Fanari:** Writing – review & editing, Investigation, Project administration, Validation.

Declaration of competing interest

All the authors have no declarations to make.

References

[1] Carroll JD, Mack MJ, Vemulapalli S, et al. STS-ACC TVT registry of transcatheter aortic valve replacement. Ann Thorac Surg. Feb 2021;111(2):701–22. https://doi.org/10.1016/j.athoracsur.2020.09.002.

[2] Philipsen TE, Collas VM, Rodrigus IE, et al. Brachiocephalic artery access in transcatheter aortic valve implantation: a valuable alternative: 3-year institutional experience. Interact Cardiovasc Thorac Surg. Dec 2015;21(6):734–40. https://doi.org/10.1093/icvts/ivv262.

[3] Nishimura RA, Otto CM, Bonow RO, et al. AHA/ACC focused update of the 2014 AHA/ACC Guideline for the Management of Patients With Valvular Heart Disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. Circulation. 2017;135(25):e1159–95. https://doi.org/10.1161/CIR.0000000000000503.

[4] Biasco L, Ferrari E, Pedrazzini G, et al. Access sites for TAVI: patient selection criteria, technical aspects, and outcomes. Front Cardiovasc Med. 2018;5:88. https://doi.org/10.3389/fcvm.2018.00088.

[5] O'Neill BP. Transcarotid transcatheter aortic valve replacement: not just a pain in the neck. JACC Cardiovasc Interv. Oct 24 2016;9(20):2121–3. https://doi.org/10.1016/j.jcin.2016.09.022.

[6] Biancari F, Rosato S, D'Errigo P, et al. Immediate and intermediate outcome after transapical versus transfemoral transcatheter aortic valve replacement. Am J Cardiol. Jan 15 2016;117(2):245–51. https://doi.org/10.1016/j.amjcard.2015.10.036.

[7] Azmoun A, Amabile N, Ramadan R, et al. Transcatheter aortic valve implantation through carotid artery access under local anaesthesia. European Journal of Cardio-thoracic Surgery: Official Journal of the European Association for Cardio-thoracic Surgery. Oct 2014;46(4):693–8. discussion 698. https://doi.org/10.1093/ejcts/ezt619.

[8] Campelo-Parada F, Rodes-Cabau J, Dumont E, et al. A novel transcarotid approach for implantation of balloon-expandable or self-expandable transcatheter aortic valves. Can J Cardiol. Dec 2016;32(12):1575.e9–1575.e12. https://doi.org/10.1016/j.cjca.2016.03.015.

[9] Chamandi C, Abi-Akar R, Rodes-Cabau J, et al. Transcarotid compared with other alternative access routes for transcatheter aortic valve replacement. Circ Cardiovasc Interv. Nov 2018;11(11):e006388. https://doi.org/10.1161/CIRCINTERVENTIONS.118.006388.

[10] Damluji AA, Murman M, Byun S, et al. Alternative access for transcatheter aortic valve replacement in older adults: a collaborative study from France and United States. Catheter Cardiovasc Interv. Nov 15 2018;92(6):1182–93. https://doi.org/10.1002/ccd.27690.

[11] Debry N, Delhaye C, Azmoun A, et al. Transcarotid transcatheter aortic valve replacement: general or local anesthesia. JACC Cardiovasc Interv. Oct 24 2016;9(20):2113–20. https://doi.org/10.1016/j.jcin.2016.08.013.

[12] Kirker EB, Hodson RW, Spinelli KJ, Korngold EC. The carotid artery as a preferred alternative access route for transcatheter aortic valve replacement. Ann Thorac Surg. Aug 2017;104(2):621–9. https://doi.org/10.1016/j.athoracsur.2016.12.030.

[13] Modine T, Sudre A, Delhaye C, et al. Transcutaneous aortic valve implantation using the left carotid access: feasibility and early clinical outcomes. Ann Thorac Surg. May 2012;93(5):1489–94. https://doi.org/10.1016/j.athoracsur.2012.01.030.

[14] Thourani VH, Gunter RL, Neravetla S, et al. Use of transaortic, transapical, and transcarotid transcatheter aortic valve replacement in inoperable patients. Ann Thorac Surg. Oct 2013;96(4):1349–57. https://doi.org/10.1016/j.athoracsur.2013.05.068.

[15] Thourani VH, Li C, Devireddy C, et al. High-risk patients with inoperative aortic stenosis: use of transapical, transaortic, and transcarotid techniques. Ann Thorac Surg. Mar 2015;99(3):817–23. discussion 823-5. https://doi.org/10.1016/j.athoracsur.2014.10.012.

[16] Paone G, Eng M, Kabbani LS, et al. Transcatheter aortic valve replacement: comparing transfemoral, transcarotid, and transcaval access. Ann Thorac Surg. Oct 2018;106(4):1105–12. https://doi.org/10.1016/j.athoracsur.2018.04.029.

[17] Folliguet T, Laurent N, Bertram M, et al. Transcarotid transcatheter aortic valve implantation: multicentre experience in France. European Journal of Cardio-thoracic Surgery: Official Journal of the European Association for Cardio-thoracic Surgery. Jan 1 2018;53(1):157–61. https://doi.org/10.1093/ejcts/ezx264.

[18] Kallinikou Z, Berger A, Ruchat P, et al. Transcutaneous aortic valve implantation using the carotid artery access: feasibility and clinical outcomes. Arch Cardiovasc Dis. Jun-Jul 2017;110(6–7):389–94. https://doi.org/10.1016/j.acvd.2016.10.005.

[19] Pozzi M, Grinberg D, Obadia JF, et al. Transcatheter aortic valve implantation using the left transcarotid approach in patients with previous ipsilateral carotid endarterectomy. Catheter Cardiovasc Interv. Jun 2015;85(7):E203–9. https://doi.org/10.1002/ccd.25779.

[20] Moher D, Cook DJ, Eastwood S, Olkin I, Rennie D, Stroup DF. Improving the quality of reports of meta-analyses of randomised controlled trials: the QUOROM statement. Quality of reporting of meta-analyses. Lancet. Nov 27 1999;354(9193):1896–900. https://doi.org/10.1016/s0140-6736(99)04149-5.

[21] Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med. Aug 18 2009;151(4):264–9. https://doi.org/10.7326/0003-4819-151-4-200908180-00135. (W64).

[22] Sterne JA, Hernan MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ (Clinical Research Ed). Oct 12 2016;355:i4919. https://doi.org/10.1136/bmj.i4919.

[23] Praz F, Wenaweser P. Transcatheter aortic valve replacement via the transcarotid access. Circ Cardiovasc Interv. Nov 2018;11(11):e007459. https://doi.org/10.1161/CIRCINTERVENTIONS.118.007459.

[24] Mylotte D, Sudre A, Teiger E, et al. Transcarotid transcatheter aortic valve replacement: feasibility and safety. JACC Cardiovasc Interv. Mar 14 2016;9(5):472–80. https://doi.org/10.1016/j.jcin.2015.11.045.

[25] Madigan M, Atoui R. Non-transfemoral access sites for transcatheter aortic valve replacement. J Thorac Dis. Jul 2018;10(7):4505–15. https://doi.org/10.21037/jtd.2018.06.150.

[26] Grover FL, Vemulapalli S, Carroll JD, et al. 2016 annual report of the Society of Thoracic Surgeons/American College of Cardiology Transcatheter Valve Therapy Registry. J Am Coll Cardiol. 2017;69(10):1215–30. https://doi.org/10.1016/j.jacc.2016.11.033.

[27] Bleiziffer S, Piazza N, Mazzitelli D, Opitz A, Bauernschmitt R, Lange R. Apical-access-related complications associated with trans-catheter aortic valve implantation. European journal of Cardio-thoracic surgery: Official Journal of the European Association for Cardio-thoracic Surgery. Aug 2011;40(2):469–74. https://doi.org/10.1016/j.ejcts.2010.11.076.

[28] Papadopoulos N, Wenzel R, Thudt M, et al. A decade of transapical aortic valve implantation. Ann Thorac Surg. Sep 2016;102(3):759–65. https://doi.org/10.1016/j.athoracsur.2016.02.104.

[29] Ribeiro HB, Dahou A, Urena M, et al. Myocardial injury after transaortic versus transapical transcatheter aortic valve replacement. Ann Thorac Surg. Jun 2015;99(6):2001–9. https://doi.org/10.1016/j.athoracsur.2015.01.029.

[30] Barbash IM, Dvir D, Ben-Dor I, et al. Impact of transapical aortic valve replacement on apical wall motion. Journal of the American Society of Echocardiography: Official Publication of the American Society of Echocardiography. Mar 2013;26(3):255–60. https://doi.org/10.1016/j.echo.2012.11.003.

[31] Doshi R, Shah P, Meraj PM. In-hospital outcomes comparison of transfemoral vs transapical transcatheter aortic valve replacement in propensity-matched cohorts with severe aortic stenosis. Clin Cardiol. Mar 2018;41(3):326–32. https://doi.org/10.1002/clc.22866.

[32] Arai T, Romano M, Lefèvre T, et al. Direct comparison of feasibility and safety of transfemoral versus transaortic versus transapical transcatheter aortic valve replacement. J Am Coll Cardiol Intv. 2016;9(22):2320. https://doi.org/10.1016/j.jcin.2016.08.009.

[33] Garcia DC, Benjo A, Cardoso RN, et al. Device stratified comparison among transfemoral, transapical and transubclavian access for Transcatheter Aortic Valve Replacement (TAVR): a meta-analysis. Int J Cardiol. Mar 15 2014;172(2):e318–21. https://doi.org/10.1016/j.ijcard.2013.12.162.