Comparison of Transcarotid vs. Transfemoral Transcatheter Aortic Valve Implantation

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Background: Recently, the carotid artery has been used as an alternative approach for transcatheter aortic valve implantation (TAVI). The aim of this study was to prove the safety and feasibility of transcarotid (TC) vs. transfemoral (TF) TAVI.

Methods and Results: This retrospective study enrolled 726 consecutive patients with severe symptomatic aortic stenosis. All patients underwent TC-TAVI or TF-TAVI at Hôpital Haut-Lévêque, Bordeaux Heart University Hospital between September 2012 and October 2017. The TC-TAVI (n=83) and TF-TAVI (n=643) groups were compared statistically. The EuroSCORE II was significantly higher (8.2 ± 6.7 vs. 6.4 ± 5.5 ; $P=0.007$) and rates of current smoking, dyslipidemia and peripheral arterial disease were higher in the TC-TAVI than TF-TAVI group. All TC-TAVIs and 9.3% of TF-TAVIs were performed under general anesthesia. Radiation time was significantly shorter in the TC-TAVI than TF-TAVI group (14.5 ± 6.0 vs. 23.0 ± 10.8 min; $P<0.001$). Postimplant balloon valvuloplasty was performed more frequently in the TF-TAVI than TC-TAVI group (7.2% vs. 19.4%; $P=0.006$). Postoperative echocardiographic data were similar between the 2 groups, and there were no significant differences in 30-day mortality (8.4% vs. 5.0%; $P=0.189$) or stroke rate (1.2% vs. 2.6%; $P=0.428$) between the TF-TAVI and TC-TAVI groups.

Conclusions: The feasibility and 30-day safety of TC-TAVI and TF-TAVI are similar. When TF-TAVI is not suitable anatomically for a particular patient, TC-TAVI is a preferable alternative.

Key Words: Aortic stenosis; Carotid arteries; Transcatheter aortic valve implantation/replacement

The worldwide rate of transcatheter aortic valve implantation (TAVI) is increasing in high-risk patients with severe symptomatic aortic stenosis, and patients with TAVI have an acceptable 5-year survival rate.¹ The gold standard access for TAVI is the transfemoral (TF) approach because it is associated with a lower procedural mortality, especially compared with a transapical approach.^{2–5} When the iliofemoral artery is severely tortuous, calcified or too small for introduction of the device, a transapical, trans-subclavian, transaxillary or transcarotid (TC) approach may be used.⁶

Recently, the carotid artery has been used as an alternative approach for TAVI (Figure).^{6–14} Modine et al¹⁵ published the first case report of TAVI via the left carotid artery in 2010, and Mylotte et al¹³ reported acceptable 30-day and 1-year outcomes in patients in the French Transcarotid TAVR Registry.

The aim of this study was to prove the safety and feasibility of TC-TAVI compared with TF-TAVI.

Methods

Subjects

The present retrospective study enrolled 726 consecutive patients with severe symptomatic aortic stenosis. All patients underwent TC- or TF-TAVI at Hôpital Haut-Lévêque, Bordeaux Heart University Hospital between September 2012 and October 2017.

The TAVI approach was selected by a multidisciplinary heart team. All patients underwent preoperative computed tomography angiography (CTA) of the neck, chest, and abdomen, and ultrasonography of the neck vessels. A TF approach was the first choice for TAVI. When the iliac artery was heavily calcified, tortuous or had a diameter <5 mm, a TC approach was selected instead, and CTA of the head or cerebral magnetic resonance angiography was performed. Both right and left common carotid arteries were usable, with a preference for the right side. Other approaches, such as transapical, transaortic, or trans-subclavian, were selected in case of the following anatomic problems: (1) small diameter (<5.5 mm) of the selected

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common carotid artery; (2) massive calcification of the selected common carotid artery; (3) significant stenosis (>50%) of the contralateral common carotid artery; and (4) malformation in the circle of Willis, considered a high risk for hypoperfusion during clamping of 1 common carotid artery.

Surgical Technique of TC-TAVI

TC-TAVI was performed in a hybrid operating room in patients under general anesthesia. All patients were monitored using transesophageal echocardiography and continuous radial arterial pressure measurement. The proximal right common carotid artery and internal jugular vein were exposed through a 4-cm lateral cervical incision along the anterior edge of the sternocleidomastoid, which was more caudal than the incision that is typically used for normal endarterectomy. The common carotid artery was dissected sharply to avoid injury to the vagus nerve. After administration of heparin (100 units/kg, activated clotting time >250 s), 2 6-Fr sheaths were inserted through the internal jugular vein and common carotid using the Seldinger technique. A pacing lead was placed in the right ventricle through the sheath in the internal jugular vein. A stiff wire was positioned in the left ventricle through the common carotid artery, and then the 6-Fr sheath was changed to a delivery sheath. The delivery sheath was positioned in line with the aortic valve. After balloon aortic valvuloplasty, the valve to be implanted was delivered into the native aortic valve and deployed without a neck vessel protection device. After the delivery catheter was removed, aortography was performed. The distal side of the common carotid artery was clamped. The delivery sheath was removed with clamping of the proximal side. The common carotid artery opening was closed with a single running 5–0 monofilament suture. The patency of the common carotid artery was verified with aortography. The initial incision was closed in 2 layers, with 1 drain inside.

Statistical Analysis

Values are presented as the mean±SD or as n (%). Continuous variables were analyzed using Student's t-test. Categorical variables were analyzed using a Chi-squared test. Analyses were performed using R version 3.4.3 (R Foundation for Statistical Computing, Vienna, Austria).

Results

TC-TAVI and TF-TAVI were performed in 83 and 643 patients, respectively. All implantations were performed between September 2012 and October 2017. Patients who underwent TAVI with the transapical, transaortic or trans-subclavian approach were excluded from this study because of the small number of such patients (n=11, 18 and 10, respectively). The TAVI approach was selected by a multidisciplinary conference that included cardiologists, cardiovascular surgeons, anesthesiologists, ultrasonographers, and radiographic engineers.

Patient demographics and preoperative characteristics are given in **Table 1**. The percentage of males was significantly higher in the TC-TAVI than TF-TAVI group (65.1% vs. 53.7%, respectively; $P=0.049$). The rate of current smokers was also significantly higher in the TC-TAVI than TF-TAVI group (15.7% vs. 2.0%, respectively; $P<0.001$). There were no significant differences in the rate of preoperative stroke or transient ischemic attack between the 2

Figure. The transcarotid approach.

groups (9.6% vs. 11.8%, respectively; $P=0.559$). Rates of dyslipidemia and peripheral arterial disease were significantly higher in the TC-TAVI than TF-TAVI group (79.5% vs. 66.1% [$P=0.014$] and 61.4% vs. 20.5% [$P<0.001$], respectively). Massive peripheral arterial disease was 1 of the reasons why TC-TAVI was selected. The surgical risk based on the EuroSCORE II was significantly higher in the TC-TAVI than TF-TAVI group (8.2 ± 6.7 vs. 6.4 ± 5.5 , respectively; $P=0.007$).

Perioperative outcomes are given in **Table 2**. All TC-TAVIs were performed under general anesthesia, whereas most TF-TAVIs were performed under local anesthesia. There was no significant difference in the operation time between the 2 groups (76.7 ± 28.8 vs. 75.4 ± 33.2 min, respectively; $P=0.809$); however, radiation time was significantly shorter in the TC-TAVI than TF-TAVI group (14.5 ± 6.0 vs. 23.0 ± 10.8 min, respectively; $P<0.001$). Edwards TAVI valves and Medtronic TAVI valves were used equally. Postimplant balloon valvuloplasty was performed more frequently in the TF-TAVI than TC-TAVI group (7.2% vs. 19.4, respectively; $P=0.006$). One patient (1.2%) required repair of the common carotid artery with a bovine pericardial patch because of a stenosis that was observed on angiography.

Postoperative outcomes are listed in **Table 3**. There were no significant differences between the 2 groups in echocardiographic data, hospital stay (12.4 ± 7.7 vs. 12.0 ± 8.7 days; $P=0.729$), early safety (86.7% vs. 86.1%; $P=0.993$), 30-day clinical efficacy (79.5% vs. 83.6%; $P=0.341$), procedural mortality (2.4% vs. 1.2%; $P=0.391$), 30-day mortality (8.4% vs. 5.0%; $P=0.189$), or complications. One ipsilateral transient ischemic attack (1.2%) and 1 ipsilateral stroke (1.2%) were observed in the TC-TAVI group, and these patients completely recovered 30 days after the intervention. Infectious complications, such as pneumonia or urinary tract infection, were recorded in 5 patients (6.0%) in the TC-TAVI group, but no wound infections were observed.

One patient (1.2%) in the TC-TAVI group required repair of the common carotid artery because of hematoma. No cerebral nerve injury was observed in the TC-TAVI group.

Discussion

This study proved that TC-TAVI was not inferior to

Variable	TC-TAVI (n=83)	TF-TAVI (n=643)	P value
Age (years)	80.0±7.5	81.4±8.4	0.068
Male	54 (65.1)	345 (53.7)	0.049
BMI (kg/m ²)	26.4±4.7	27.3±6.1	0.207
Current smoker	13 (15.7)	13 (2.0)	<0.001
NYHA Class III or IV	47 (56.6)	331 (51.5)	0.377
Cardiac characteristics			
LVEF (%)	51.5±14.7	53.1±13.9	0.312
Aortic valve mean gradient (mmHg)	45.0±16.6	46.6±17.8	0.450
Aortic valve surface (cm ²)	0.8±0.4	0.7±0.4	0.395
Cardiac comorbidities			
Atrial fibrillation	32 (38.6)	259 (40.3)	0.763
Myocardial infarction	16 (19.2)	95 (14.8)	0.283
Prior cardiac operation	20 (24.0)	151 (23.4)	0.901
Prior CABG	19 (22.9)	109 (17.0)	0.181
Prior PCI	35 (42.2)	242 (37.6)	0.424
Pacemaker	13 (15.7)	93 (14.5)	0.771
Other comorbidities			
Hypertension	67 (80.7)	483 (75.1)	0.262
Dyslipidemia	66 (79.5)	425 (66.1)	0.014
Stroke or TIA	8 (9.6)	76 (11.8)	0.559
Diabetes mellitus	26 (31.3)	173 (26.9)	0.396
COPD	29 (34.9)	233 (36.2)	0.817
Peripheral arterial disease	51 (61.4)	132 (20.5)	<0.001
Creatinine (mg/dL)	1.4±1.2	1.2±0.8	0.758
STS score	6.4±3.3	6.7±4.3	0.457
Logistic EuroSCORE	24.2±13.3	21.3±12.4	0.051
EuroSCORE II	8.2±6.7	6.4±5.5	0.007

Unless indicated otherwise, data are given as the mean±SD or as n (%). CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; PCI, percutaneous coronary intervention; STS, Society of Thoracic Surgeons; TC-TAVI, transcatheter transcatheter aortic valve implantation; TF-TAVI, transfemoral transcatheter aortic valve implantation; TIA, transient ischemic attack.

Variable	TC-TAVI (n=83)	TF-TAVI (n=643)	P value
Device success	81 (97.5)	604 (93.9)	0.175
General anesthesia	83 (100)	62 (9.6)	<0.001
Local anesthesia	0 (0)	581 (90.3)	
Radiation time (min)	14.5±6.0	23.0±10.8	<0.001
Operation time (min)	76.7±28.8	75.4±33.2	0.809
Conversion to surgical AVR	0 (0)	0 (0)	1.000
Valve in valve	3 (3.6)	56 (8.7)	0.110
Edwards SAPIEN valve	45 (54.2)	309 (48.1)	0.291
Medtronic CoreValve	39 (47.0)	334 (51.9)	0.395
Pre-implant balloon valvuloplasty	35 (42.1)	227 (35.3)	0.220
Postimplant balloon valvuloplasty	6 (7.2)	125 (19.4)	0.006

Unless indicated otherwise, data are given as the mean±SD or as n (%). AVR, aortic valve replacement. Other abbreviations as in Table 1.

TF-TAVI with regard to safety and feasibility in a large number of subjects.

Carotid surgery (endarterectomy) was first performed in 1954 in a patient with cerebral symptoms.¹⁶ Subsequently, the effectiveness of endarterectomy for patients with severe

carotid artery stenosis was proven in several large randomized trials in the 1990s.¹⁷ However, because endarterectomy includes occlusion and opening the carotid artery, perioperative complications such as stroke or death remain a major concern.^{18,19} Other surgical complications of end-

Table 3. Postoperative Outcomes

Variable	TC-TAVI (n=83)	TF-TAVI (n=643)	P value
Mean gradient (mmHg)	10.3±4.6	10.7±6.6	0.558
Aortic valve surface (cm ²)	1.8±0.6	1.7±0.7	0.110
Aortic regurgitation ≥ Grade 2	12 (14.4)	94 (14.6)	0.969
Hospital stay (days)	12.4±7.7	12.0±8.7	0.729
Early safety ^A	72 (86.7)	558 (86.1)	0.993
30-day clinical efficacy ^B	66 (79.5)	538 (83.6)	0.341
Procedural mortality	2 (2.4)	8 (1.2)	0.391
30-day mortality	7 (8.4)	32 (5.0)	0.189
TIA	1 (1.2)	1 (0.2)	0.086
Stroke	1 (1.2)	17 (2.6)	0.428
Tamponade	1 (1.2)	9 (1.4)	0.886
Bleeding with shock	0 (0)	8 (1.2)	0.307
New dialysis	0 (0)	7 (1.1)	0.339
Myocardial infarction	1 (1.2)	2 (0.3)	0.232
Major vascular complication	1 (1.2)	32 (4.9)	0.121
Infectious complication	5 (6.0)	45 (7.0)	0.741
Permanent pacemaker implantation	17 (20.5)	135 (21.0)	0.914

Unless indicated otherwise, data are given as the mean±SD or as n (%). ^AEarly safety is defined as the absence of mortality, stroke, life-threatening bleeding, acute kidney injury Stage 2 or 3, coronary obstruction, major vascular complications, and valve-related dysfunction requiring open surgery or re-intervention. ^BClinical efficacy is defined as the absence of mortality, stroke, rehospitalization, New York Heart Association Class III or IV, valve-related dysfunction with a mean residual gradient >20 mmHg, or paravalvular leak Grade III or IV. Abbreviations as in Table 1.

arterectomy include cranial nerve injury, wound hematoma, and wound infection.¹⁸ The same concerns are present with TC-TAVI, because the manipulations are similar with both procedures. Nevertheless, no approach-related death was observed in the TC-TAVI group in the present study, and the rates of death, stroke, and other complications were not significantly different between the TC-TAVI and TF-TAVI groups.

The surgical technique of TC-TAVI is not complicated because of the superficial location of the carotid artery. The occurrence of vascular complications and total operation time were not significantly different between the 2 groups in this study. Both Edwards valves and Medtronic valves can be used for TC-TAVI.

In the present study, more men underwent TC-TAVI than TF-TAVI (65.1% vs. 53.7%; $P=0.049$), although men normally have larger arteries for iliofemoral access. In addition, rates of current smokers and a history of peripheral arterial disease were higher in the TC-TAVI than TF-TAVI group. We believe that the difference in these morbidities between sexes may influence the diameter and quality of iliofemoral access, which can lead to contraindication of the TF approach.

Mylotte et al¹³ reported encouraging 30-day and 1-year outcomes in 96 patients who underwent TC-TAVI (6.3% and 16.7%, respectively). Although TC-TAVI included a neck vessel procedure, there was no stroke during the first 30 days after TAVI in the study of Mylotte et al,¹³ who suggested 4 potential stroke mechanisms during TC-TAVI: (1) embolization due to arterial puncture; (2) access site trauma leading to thrombosis; (3) inadequate collateral perfusion; and (4) embolization of debris from the aortic valve. Furthermore, Mylotte et al¹³ suggested that the risk of embolization from debris may be reduced in TC-TAVI by protecting the neck vessel with a sheath during the intervention. In the present study there was only 1 (1.2%)

ipsilateral stroke in the TC-TAVI group, and we believe that this was because the CoreValve prosthesis was recaptured 3 times and the clamp time of the right common carotid artery was 22 min.

The right common carotid artery is preferable to the left as an access site for TAVI. The right common carotid artery provides the same axis to the aortic valve, and the manipulation of the device is more direct and easier from the right side. Mylotte et al¹³ performed TC-TAVI using the left common carotid artery in 96 patients and found that 4 of 6 transient ischemic attacks occurred on the right side. They raised the possibility that embolization from the aortic valve may preferentially access the cerebral vasculature via the right common carotid artery.¹³

Most previous studies reported better results with the TF than transapical approach.²⁰ Sawa et al²¹ reported that 6-month all-cause mortality, cardiac mortality, and 5-year cardiac mortality were higher with transapical TAVI than TF-TAVI, and suggested that these outcomes were related to a higher learning curve with transapical TAVI. Kirker et al⁶ compared TF, transapical, and TC approaches and found that the transapical approach was inferior to the other approaches because it was associated with significantly higher in-hospital mortality and stroke rates (16.7% and 8.0%, respectively). In addition, compared with the subclavian approach, Kirker et al⁶ recommended TC-TAVI because the right common carotid artery approach gives a straight path to the aortic valve, which may simplify the placement of the prostheses.

Folliguet et al²² also suggested that the subclavian approach could be less favorable for TAVI due to its small diameter and tortuosity. We also believe that the exposure of the subclavian artery is more complicated in obese patients. In the present study, there was a shorter radiation time and less frequent postimplant balloon valvuloplasty in the TC-TAVI than TF-TAVI group; however, the total

operation time was not affected because it took longer to expose and repair the carotid artery in the TC-TAVI group.

Thourani et al²³ reported excellent results with TC-TAVI in 11 patients, with no strokes or deaths in the first 30 days. However, their strategy used the transapical approach as a second choice and was different from ours. A direct comparison of transapical TAVI and TC-TAVI in a larger number of subjects is needed.

Azmoun et al⁹ recommended TC-TAVI under local anesthesia to reduce the risk of respiratory complications in elderly and frail patients. Debry et al¹² showed that, compared with TC-TAVI under general anesthesia, TC-TAVI under local anesthesia with light sedation using remifentanyl without intubation reduced the risk of procedural stroke because changes in consciousness during the carotid cross-clamp test gave more information in addition to cerebral oximetry.

In the present study, more patients smoked and had peripheral arterial disease in the TC-TAVI than TF-TAVI group because our indication for TC-TAVI included arterial calcification or arteriosclerosis. In addition, the EuroSCORE II was higher in the TC-TAVI than TF-TAVI group, which may have been due to a higher rate of peripheral arterial disease. The mortality in the TC-TAVI group did not differ significantly from that in the TF-TAVI group, despite a higher EuroSCORE II in the former. In short, TC-TAVI was a preferable alternative when TF-TAVI was not suitable because of peripheral arterial disease.

In a large cohort study, Halm et al²⁴ reported a higher 30-day stroke rate (3.28%) after carotid endarterectomy than we observed with TC-TAVI, which confirms the safety of carotid artery manipulation in TC-TAVI.

Study Limitations

The present study has several limitations. First, this study validated only the non-inferiority of TC-TAVI compared with TF-TAVI. Direct comparison of TC, transapical, trans-aortic, and the other approaches with randomization is needed to determine the optimal approach for TAVI. Second, we enrolled subjects at a single institution, and the design of the study was retrospective. Third, patient demographics were significantly different with regard to gender and several comorbidities. These differences may have affected the outcomes. Fourth, we compared outcomes only within the first 30 days postoperatively. The present findings should be validated in a larger and longer prospective matched study.

Conclusions

TC-TAVI has short-term safety and feasibility that are similar to TF-TAVI. When TF-TAVI is not suitable anatomically for a particular patient, TC-TAVI is a preferable alternative.

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