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par

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COMPLICATIONS VASCULAIRES DES PROCEDURES TAVI A L'ERE DES SYSTEMES MINIATURISES

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RESUME

COMPLICATIONS VASCULAIRES DES PROCEDURES TAVI A L'ERE DES SYSTEMES MINIATURISES

INTRODUCTION : Les complications vasculaires (CVs) des procédures TAVI (Transcatheter Aortic Valve Implantation) sont associées à une augmentation de la morbi-mortalité intra-hospitalière. Alors que les systèmes d'implantations valvulaires et de fermeture vasculaire ont connu de nombreuses améliorations techniques, peu de données récentes sont disponibles dans la littérature concernant l'incidence actuelle de ces complications et leur impact pronostique.

MATERIEL et METHODE : Nous avons inclus dans notre étude l'ensemble des patients ayant bénéficié d'une procédure TAVI en 2017 aux CHRU de Tours et de Rennes. Les complications vasculaires étaient recueillies selon les critères du Valve Academic Research Consortium (VARC-2). Les données cliniques et scanographiques étaient recueillies par un investigateur indépendant des procédures TAVI.

RESULTATS : Quatre cent soixante-dix-neuf patients ont été inclus prospectivement. L'incidence des CVs était de 25.9% (n=124 patients) dont 2.9% majeures (n=14) et 23% mineures (n=111). Les CVs étaient liées au point de ponction principal dans 69% des cas et au point de ponction secondaire dans 31% des cas. Les traitements mis en œuvre étaient médicaux (compressif) dans 76%, endovasculaires dans 9% et chirurgicaux dans 15% des CVs. Les facteurs de risques pour l'ensemble des CVs étaient : l'Iliac Morphology Score, le rapport des diamètres entre l'introducteur et le diamètre iliofémoral minimal (SIFAR), les calcifications iliofémorales modérées ou sévères et les tortuosités iliofémorales modérées ou sévères. Pour les CVs majeures, seul SIFAR était un facteur de risque. Les CVs étaient associées à une augmentation significative de l'incidence des saignements majeurs et des accidents vasculaires cérébraux, ainsi qu'à un allongement de la durée d'hospitalisation. Les CVs majeures augmentaient significativement la mortalité intra-hospitalière (30.7%, vs 1.1% pour le groupe CVs mineures, et 1.3% pour le groupe sans CVs ; log rank $p<0.0001$). A 1 an de suivi, les CVs majeures augmentaient la mortalité (40.6%, vs 5.6% pour le groupe CVs mineures, et 5.6% pour le groupe sans CVs ; log rank $p<0.0001$, adjusted HR (95%CI) = 18.69[7.72-61.13]). Ceci n'était pas observé après CVs mineures.

CONCLUSION : A l'ère de la miniaturisation des systèmes d'implantation valvulaire, plus d'un quart des procédures TAVI sont associées à des CVs, le plus souvent mineures. Dans notre expérience, le point de ponction secondaire est à l'origine d'un tiers des CVs et doit par conséquent être surveillé activement. La détection précoce des CVs est nécessaire pour prévenir la transformation d'une complication mineure en majeure.

Mots clés : TAVI, complications vasculaires, VARC-2, SIFAR, calcifications iliofémorales, tortuosités iliofémorales.

RESUME

VASCULAR COMPLICATIONS AFTER TRANSCATHETER AORTIC VALVE IMPLANTATION IN THE ERA OF MINIATURIZED SYSTEMS

INTRODUCTION: Vascular complications (VCs) of TAVI (Transcatheter Aortic Valve Implantation) procedures are associated with an increased risk of morbidity and mortality. While delivery systems and vascular closure devices have undergone many technical improvements, few recent data are available in the literature regarding the current incidence of VCs and their prognostic impact.

MATERIAL and METHODS: We included in our study all the patients who benefited from a TAVI procedure in 2017 at the University Hospitals of Tours and Rennes. Vascular complications were collected according to the Valve Academic Research Consortium (VARC-2) criteria. Clinical and CT data were collected by an independent investigator of TAVI procedures.

RESULTS : Four hundred and seventy-nine patients were included prospectively. The incidence of VCs was 25.9% (n = 124 patients), of which 2.9% were major (n = 14) and 23% minor (n = 111). VCs were related to the main puncture point in 69% of cases compared to 31% at the secondary puncture site. The treatments implemented were medical (compressive) in 76%, endovascular in 9% and surgical in 15% of VCs. The risk factors for all the VCs were: Iliac Morphology Score, the ratio of diameters between introducer and minimal iliofemoral diameter (SIFAR), moderate or severe iliofemoral calcifications, and moderate or severe iliofemoral tortuosity. For major VCs, only SIFAR was a risk factor. VCs were associated with a significant increase in major bleeding, stroke, and length of hospital stay. The major VCs significantly increased intra-hospital mortality (30.7% vs 1.1% minor CVs and 1.3% no CVs, log rank p <0.0001). At 1 year of follow-up, the major VCs increased mortality (40.6% vs 5.6% minor VCs and 5.6% not VCs, log rank p <0.0001, HR (95% CI) = 18.69 [7.72-61.13]) contrary to the VCs minor.

CONCLUSION : In the era of miniaturization of valve delivery systems, more than a quarter of TAVI procedures are associated with VCs, mostly minor ones. In our experience, the secondary puncture point is responsible for one-third of VCs, which must also be actively monitored. Early detection of VCs is necessary to prevent the transformation of a minor to a major complication.

Key words : TAVI, vascular complications, VARC-2, SIFAR, iliofemoral calcifications, iliofemoral tortuosity.

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SERMENT D'HIPPOCRATE

En présence des Maîtres de cette Faculté,

de mes chers condisciples

et selon la tradition d'Hippocrate,

je promets et je jure d'être fidèle aux lois de l'honneur

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si je suis fidèle à mes promesses.

Que je sois couvert d'opprobre

et méprisé de mes confrères

si j'y manque.

GROUPE ETHIQUE D'AIDE A LA RECHERCHE CLINIQUE POUR LES PROTOCOLES DE RECHERCHE NON SOUMIS AU COMITE DE PROTECTION DES PERSONNES
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TABLES DES MATIERES

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A ma famille

A ma belle famille

A mes amis, TOUS sans exception

Vascular Complications After Transcatheter Aortic Valve Implantation in the era of miniaturized systems

INTRODUCTION

Transcatheter aortic valve implantation (TAVI) became in recent years a standard treatment of severe aortic valve stenosis for patients at high and intermediate operative risk (1–4). While transfemoral access for TAVI is usually the preferred approach in most experienced centers, vascular complications (VCs) have been shown to increase mortality risk (5–7). The Valve Academic Research Consortium statement has standardized definitions of VCs after TAVI to allow a better comparison between studies (8). Until now, most studies reported VCs using first-generation delivery systems, via a 22- or 24-F sheath (5,9) and definition of events was not always clear.

The objective of this prospective bi-centric study was to report the incidence, predictors, and impact of VCs during TAVI procedure in the era of miniaturized introducer systems using a standardized definition of events.

METHODS:

From January 2017 to December 2017, we enrolled all patients who benefit from a TAVI procedure in the University Hospitals of Tours and Rennes, France. All procedures and approaches were counted to have an accurate and exhaustive estimate of vascular complications over a year. Before TAVI implantation, a multidisciplinary consultation meeting with cardiologist, cardiac surgeon, echocardiographist and anesthesiologist, was made to check the indication and to decide on the way of access. Consent was obtained from each patient with the agreement of the Institutional Ethics Committee and was registered in the France TAVI database (10). All patients have undergone CT angiography to evaluate the sizing of the prosthesis and vascular anatomy. Baseline characteristics, risk score, and

procedural data were collected from the medical records of each patient. According to hospital protocol, oral anticoagulants were stopped, and antiplatelet drugs were continued.

The two most common implanted prostheses were the balloon-expandable SAPIEN 3 (size 23-, 26-, 29mm; Edwards Lifesciences, Irvine, California) or the self-expanding Corevalve EVOLUT R (size 23-, 26-, 29-, 31-, 34mm; Medtronic, Minneapolis, Minnesota). For SAPIEN 3 prostheses, eSheath expandable introducer system (Commander delivery catheter, Edwards Lifesciences) was used with a 14-French inside diameter sheath for 23- and 26mm (equivalent to 5.8 mm at the outer diameter unexpanded), or 16-French inside diameter for 29mm prostheses (equivalent to 6.5mm at the outer diameter unexpanded) (11). For Corevalve EVOLUT R 23-, 26- and 29-mm prostheses, the EnVeo Delivery system (Medtronic, Inc) was used with a 14-French Equivalent InLine Sheath which is equivalent to 18-French (6mm) at the outer diameter. For Corevalve EVOLUT R 31 and 34mm prostheses, the introducer system was a 20-French (6,7mm) at the outer diameter (12). Three patients were implanted using Portico™ (Abbott, Santa Clara, California)) valve with Ultimum™ 18F or 19Fr introducer which is equivalent to 6.8mm and 7.3mm at the outer diameter (13).

The transfemoral approach was the preferred approach whenever possible. However, in the situation of small iliofemoral vessel diameters or vascular abnormalities, an alternative route was proposed according to preoperative CT angiography. Unfractionated heparin was injected before sheath insertion. Procedural steps were described previously (14,15). For a true percutaneous approach, ProStar XL Percutaneous Vascular Surgical System (Abbott Vascular, Santa Clara, California) or Proglide (Abbott Vascular) preclosing devices were used for the primary puncture site. Femoseal™ (Terumo Corporation), Angioseal™ (Terumo Corporation) or manual compression were used for the secondary puncture site.

In all patients, CT angiography was performed before the implantation, and several anatomical parameters were measured via the Endosize® software by an investigator before

collection of the clinical outcomes. Anatomical parameters were automatically extracted from the vessel's centerline via the software. Common iliac arteries, external iliac arteries, and common femoral arteries were treated as three segments. The iliofemoral junction was defined as the artery above or below the inguinal ligament. Parameters were: maximum diameter of the ascending, descending, suprarenal and infrarenal aorta; stenosis, circumferential calcifications, tortuosity, the maximum and minimum diameter of the iliofemoral axis. The Iliac Morphology Score (IMS Score) was calculated for each patient (16). Calcification rate of the iliofemoral access was graded from 0 to 3 : 0 = no calcification, 1 = calcification < 25% of the vessel length, 2 = calcification covering 25-50% of the vessel length, 3 = calcification > 50% of the vessel length or circumferential calcification (16). Tortuosity rate of the aorto-iliofemoral access was graded from 0 to 3 : 0 = tortuosity angle < 30° at any points of the iliofemoral access, 1 = tortuosity angle 30°-60° at any point of the iliofemoral access, 2 = tortuosity angle 60°-90° at any point of the iliofemoral access, 3 = tortuosity angle > 90° at any point of the iliofemoral access (17). Sheath to iliofemoral artery ratio (SIFAR) was calculated with the minimum iliofemoral artery diameter and the maximal delivery sheath diameter.

Primary endpoint study was the occurrence of any vascular complication, defined according to the Valve Academic Research Consortium criteria (VARC-2) (8) and divided into major and minor VCs. Of note, major VCs were classified as non-access related: aortic dissection, annulus rupture, left ventricle perforation; or access-related: hematoma/bleeding, pseudoaneurysm, closure device failure and dissection directly resulting in death, life-threatening or major bleeding, ischemia, neurological impairment, or distal embolization requiring surgery or resulting in irreversible damage. Minor VCs were all access-related: hematoma/bleeding, pseudoaneurysm, closure device failure, and dissection or embolization not meeting the criteria for major VCs. Primary vascular access (PVA) was defined as the one

by which the valve was introduced. Secondary vascular access (SVA) was defined as the one by which aortography was performed. Vascular complications were recorded for all type of vascular access: transfemoral (percutaneous or surgical), transcarotid, subclavian, transapical or transaortic, from the PVA or the SVA. Percutaneous closure device failure was defined as a failure leading to prolonged echo-guided compression (> 48 hours), endovascular stenting or surgical repair of the access site.

Treatment of vascular complications was registered in three classes: medical treatment (echo-guided compression), endovascular treatment (stenting), and surgical treatment (open surgery). Management of VCs was at the operator's discretion, in agreement with the vascular surgery team.

The secondary endpoint was survival at 30-day and one year.

Baseline characteristics, procedural, and follow-up data were prospectively collected in our local database including clinical and imaging parameters. Mortality data were obtained through the Social Security Death Index, ensuring complete survival follow-up for all patients.

For the statistical analysis of baseline characteristics, procedural data, and general outcome, we compared patients with (major and minor) VCs with patients without such complications. Considering the small number of patients with major VCs, we combined the cohort of major and minor VCs for these analyses. Categorical data were presented as numbers with percentages and compared using the Pearson chi-square test or Fisher's exact test, as appropriate. Normal distribution of continuous variables was verified using the Shapiro-Wilks test, and data were expressed accordingly as mean with standard deviation (95% confidence interval [CI]) or median with interquartile range and compared using Student's *t*-test or Mann-Whitney *U* test. Thirty-day mortality and one-year mortality were

described using the Kaplan-Meier method and compared by the log-rank test. A P-value <0.05 was statistically significant.

To determine predictors of VCs, univariate logistic regression analysis was performed using the following covariates found in the literature: age, sex, body mass index (BMI), diabetes, peripheral artery disease, chronic kidney failure, logistic Euroscore, anticoagulants use, femoral secondary puncture site, Iliac Morphologic Score (IMS), sheath-to-iliofemoral artery ratio, iliofemoral moderate-to-severe calcification and iliofemoral moderate-to-severe tortuosity. To determine clinical thresholds for quantitative data, we performed ROC analysis. Multivariate logistic regression analysis was then performed, including variables with P value < 0.20 in univariate analysis. For analysis of SIFAR, IMS score, calcifications, and tortuosity, we excluded patients with non-transfemoral access.

Statistical analyzes were conducted with SPSS software version 25.0 (IBM Corporations, Chicago, Illinois) and R-statistical software (version 3.5.0; R Foundation for Statistical Computing, Vienna, Austria) for survival analysis with the survminer package™.

RESULTS:

The patient flow chart is described in Figure 1. Baseline characteristics are divided into three groups (no VC, minor VC, major VC) and described in Table 1. Procedural and CT angiography parameters are presented in Table 2. All true percutaneous transfemoral procedures were performed under local anesthesia; only 1 patient was intubated before the procedure due to severe lumbar osteoarthritis pain. For 12 patients, local anesthesia was converted into general anesthesia.

In this cohort, 479 patients underwent TAVI procedure, including 416 femoral percutaneous approaches and 63 alternative access. The overall incidence of VCs was 26.1% (171 events in 125 patients) and among them, 14 major VCs (2.9%) and 111 minor VCs

(23,2%). Regarding minor VCs, most of events were hematoma (43%), while closure device failure, false aneurysm and dissection represented 21.6%, 12.3% and 8% of events respectively. Concerning major VCs, most of events were major bleeding (28.6%), closure device failures (28.6%) and acute limb ischemia (21.4%) while type B aortic dissection or others causes were exceptional. The proportion of VCs related to the second puncture site was 31.8% in the group minor VCs and 21.4 % in the group major VCs.

Using multinomial logistic regression, predictors of all vascular complications were: IMS score (p=0.003), sheath-to-iliofemoral ratio (p=0.002), moderate-to-severe iliofemoral calcification (p=0.002) and moderate-to-severe iliofemoral tortuosity (p<0.001) (Table 3). Importantly, neither the valve type or the vascular closure device were found to significantly influence the risk of VCs. Sheath-to-iliofemoral ratio was the only predictor of major vascular complications (p=0.001) (Table 4).

SIFAR cut-off point was 0.91, and minimal iliofemoral diameter cut-off point was 6.4mm for all VCs (figure 4, 5). The area under the curve (AUC) was 0.63 for SIFAR and 0.39 for minimal iliofemoral diameter, respectively, for all VCs. SIFAR cut-off was 0.95, and minimal iliofemoral diameter cut-off point was 6.2mm for major VCs (figure 6, 7). The AUC was 0.69 for SIFAR and 0.32 for minimal iliofemoral diameter respectively, for major VCs.

Surgery (open or endovascular) was performed in 41 patients (8.5%). Emergency treatment of majors VCs consisted in open vascular surgery in 8 patients (57.1%), endovascular stenting in 3 (21.4%) and medical treatment in 3 (21.4%) while minor VCs were mostly treated by prolonged compression (82.9%) (Figure 8, Table 5). Fourteen patients needed delayed vascular surgery performed 8.8 ± 9.8 days after the TAVI procedure and consisting in surgical closure for false aneurysm in 6 patients (42.8%), surgical drainage in 5 (35%), amputation in 2 (14%), and axillo-femoral bypass in 1 (Table 6).

The median total length of stay for all patients was 6.8 ± 4.2 days – of which 1 ± 1.8 days in the intensive care unit. Patients who developed vascular complications had a significantly longer total length of hospitalization (7.7 ± 4.8 days versus 6.5 ± 3.8 days, p=0.004). Same results were reported for intensive care unit length stay (1.4 ± 2.3 days versus 0.9 ± 1.6 days, p=0.013). Moreover, VCs were significantly associated with in-hospital major bleeding (p=0.001), decrease in haemoglobin (p=0.003), transfusion (p<0.001), stroke (major stroke p=0.018, minor stroke p=0.003) and delayed surgery reintervention (p<0.001) (Table 7).

Comparing the three groups - major VCs, minor VCs, and no VCs, the in-hospital mortality rate was respectively 30.7%, 1.1% and 1.3% (log rank p<0.0001). At one year, mortality rates were 40.6% in patients with major VCs, 5.6% with minor VCs and 5.6% without VCs (log rank p<0.0001, figure 9). In pairwise comparisons, mortality rate in patients with major VCs was statistically different from no VCs (p<0.0001) and minor VCs (p<0.0001) whereas minor VCs was not different from no VCs (p=0.91). Major VCs were associated with increased one-year mortality in univariate and multivariate analysis (adjusted HR (95%CI) = 18.69 (7.72-61.13), p<0.0001). This was not the case with minor VCs (Table 8).

DISCUSSION:

In this recent real-world cohort using last-generation introducer systems, we demonstrate that VC after TAVI remains a serious issue, concerning more than 26% of procedures. Most of VCs described in our series were minor, and only major VCs were associated with increased in-hospital and one-year mortality. Importantly, we also report that VCs are not limited to transfemoral TAVI and concern in our experience 14% of alternate access routes.

Definition and incidence

Assessing the accurate incidence of vascular complications from earlier trials were limited by the initial lack of standardized definitions and reported rates have varied widely from 1.9% to 30.7% (1,5,17). The VARC has standardized definitions for use in clinical research and using updated VARC-2 criteria, the incidence of vascular complications with older-generation of prostheses ranged from 7.4% to 21.4% in several registries (5,17). The relationship between larger sheath diameter and higher vascular access site bleeding risk is well established, and with reductions in TAVI device diameters, there has been a decline in the rate of bleeding complications over time. In a registry analysis of 26,414 patients comparing outcomes in patients who underwent TAVI between 2012 and 2013 to those who did so in 2014, the incidence of major bleeding, life-threatening or disabling bleeding and vascular complications declined from 5.5% to 4.2%, 6.4% to 4.3%, and 5.6% to 4.2%, respectively (19).

More recently, Van Kesteren et al. described in a monocentric prospectively acquired cohort with SAPIEN 3 Prosthesis an incidence of major VCs in 5.8% and minor VCs in 15% (6). The incidence of major VCs of 2.9% reported in our series is in line with these results and confirms the improvement of technology and the benefits of low-profile sheaths introduction. However, the higher incidence of minor VCs (23.2% in our series) may be explained by less frequent use of vascular ultrasound, which was not systematic in 2017 to guide the arterial puncture. Since, literature reported its beneficial influence on the prevention and management of VCs (20).

Impact on clinical outcomes

Consistent with previous studies (5,6,21), we demonstrate that minor VCs are not associated with in-hospital and 1-year survival. Only 19% of minor VCs were actively

managed (unplanned endovascular treatment or open surgery), which suggests that most of these events are benign and easily cured with medical treatment. Our results show satisfactory one year-survival rates for minor (5.6%) and no VCs (5.6%). Proper management of minor VCs in experienced teams does not impact mid and long-term survival (5,6).

Conversely, major VCs are strongly associated with in-hospital mortality (30.7%) and 1-year survival (40.6%, log-rank <0.0001) compared to minor and no VCs. Our 1-year mortality cohort for major VCs is high (40.6%) but similar to a pooled analysis of PARTNER IA and IB trial (39.4%) (5,9,22). In keeping with recent literature (6,23–25), we report that major VCs lead to open surgery in half of the cases and are associated with an increased length of hospital stay adding to the total cost of the procedure.

Concerning the links between VCs and other in-hospital outcomes, we showed an association between VCs, bleeding (minor and major), decrease in hemoglobin, and transfusion rates. Among these bleeding events, 69.8% (n=44) are in relation with the primary puncture site, 25.4% (n=16) are linked to the secondary puncture site, while other localizations are retroperitoneal (n=2) and intrapericardial (n=1). According to the literature, VCs and bleeding events are strongly associated because coming from the same cause: punctures sites.

Global stroke rate is 2.3% in our cohort, which is similar to other studies and trials reporting a 30-day risk of stroke from 2 to 5% (26,27). Regrettably, we found an association between VCs and strokes, particularly with major VCs. Five patients who presented major VCs had a stroke probably due to hemodynamic variations related to conversion to general anesthesia, bleeding and/or arterial manipulations (endovascular or surgical) to treat complications. This finding should lead us to take care of hemodynamic condition and optimize cerebral protection in case of vascular complications.

Risk factors

Traditional risk calculators, such as the STS score or the EuroSCORE, do not specifically predict the risk of VCs. In the literature, several predictors of vascular complications after TAVI are reported. Patient-related variables include female sex, renal insufficiency, diabetes mellitus, moderate-to-severe iliofemoral calcifications, and concomitant peripheral vascular disease (24). Procedural factors include sheath size > 19Fr (5,28), operator experience (29) and more recently, sheath to iliofemoral artery ratio (SIFAR) ≥1.05 seems to be the major predictor of VCs (6,21).

In our study, we distinguished predictors of all VCs (minor and major) and predictors of major VCs. We identified four factors of all VCs in multivariate analysis: IMS score, SIFAR, moderate/severe iliofemoral calcification, and moderate/severe iliofemoral tortuosity. Concerning IMS score, Blakeslee-Carter et al. reported that an IMS of ≥ 5 had the best discriminatory power to predict vascular complications (sensitivity 54% specificity 90%)(16). However, our results are less convincing (AUROC: 0.58, 95%CI: 0.40 – 0.76 versus AUROC: 0.82, 95%CI: 0.65-0.98). Concerning major VCs, SIFAR was the only predictor of complications in our series. ROC curves described an area under the curve of 0.62, in line with the outcomes reported by van Kesteren et al (6). Indeed, we think that the expandability and flexibility of new introducers make the use of this ratio less relevant than with older generation introducers. Moreover, measurement of the outer diameter of expandable introducers sheaths usually varies between the beginning of the intervention (unexpanded), during the TAVI procedure (expanded) and after implantation when the introducer is removed (unexpanded) (11). Therefore, we chose for the calculation of SIFAR the outer diameter before the introduction of the introducer, which is the most constant measure.

Complete percutaneous transfemoral access is the reference access-route for TAVI procedure. In cases of non-eligibility, alternative nontransfemoral approaches are needed. We

reported 13% of alternative access in our study with an incidence of 1.5% major VCs and 12.7% minor VCs. VCs were significantly less frequent in alternative access compared to transfemoral access (14.3% versus 27.9%, p =0.034). However, consistent with other reports (30,31) incidence of VCs was not significantly different between transfemoral TAVIs and other transarterial access (ie transcarotid and subclavian). In our series, very few patients underwent a transfemoral TAVI using a surgical cutdown. We were therefore unable to confirm the data of Hernandez-Enriquez et al, who report a 30-day vascular complication rate of 18% in the puncture group vs 6.9% in the surgical cutdown group (32).

Regarding the impact of introducer systems on vascular complications, we like others (33–35) could not find any difference between the eSheath expandable introducer system (Edwards Lifesciences) and the EnVeo Delivery system (Medtronic, Inc). Moreover, comparison of closure devices systems in our series showed no significant difference on VCs concerning the primary access site (ProGlide versus Prostar) or the secondary access site (Femoseal versus manual compression versus other systems). Whereas some studies showed an increased risk of vascular complications using the Prostar system (36–38), our data contradict these findings, which may be explained by the use of more recent delivery systems and the high level of operator experience.

Prevention

As vascular complications, especially major events, are such a major determinant of outcome after TAVI procedure, prevention is therefore of paramount importance. Knowledge of the patient's vascular anatomy and appropriate patient selection is critical, and preprocedural angio-CT plays a major role in procedural planning. Great attention should be paid toward a precise access technique, including the secondary puncture point, to avoid any possible vessel injury. Given the possible evolution of a minor to a major VC, use of

ultrasound, which has been shown to improve the first-pass success rate and reduce the number of attempts needed (39), should be therefore recommended. Finally, we also believe that active collaboration with cardiovascular surgeons may be necessary.

Limitations

Our study has several limitations. First, it is a bicentric, retrospective, non-randomized study, and therefore selection bias cannot be excluded. Second, this study included all TAVIs regardless of vascular access, which increases cohort heterogeneity and might induce statistical confusion bias. Third, because major VCs group is small in size, the search for risk factors in this group might be skewed by the numerical disproportion between our three groups, even if these seemed comparable on baseline and operative characteristics. However, our study was specifically designed to focus on VCs after TAVI procedures. Using strict VARC-2 criteria and reporting exhaustively all vascular complications regardless of access, delivery system or closure device, we propose a comprehensive overview of this life-threatening complication in a real-world and recent cohort.

CONCLUSION:

Despite smaller-caliber delivery systems and the introduction of new generation prostheses, VCs remain a significant issue of TAVI procedures, especially transfemoral. Whereas most VCs are minor and not associated with worse outcomes, major VCs are associated with an increased risk of mortality at 30-days and one-year. Great attention should be paid toward a precise access technique, including the secondary puncture point. Early and appropriate management of any VC seems also crucial to prevent a minor VCs becoming a major.

Figures:

Figure 1

Flow chart of the cohort

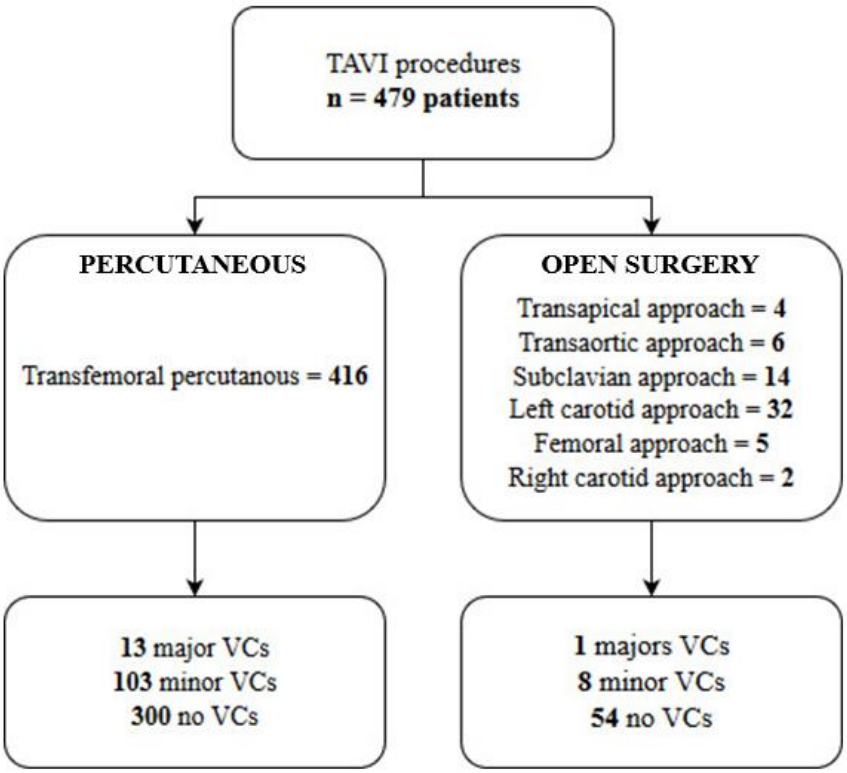
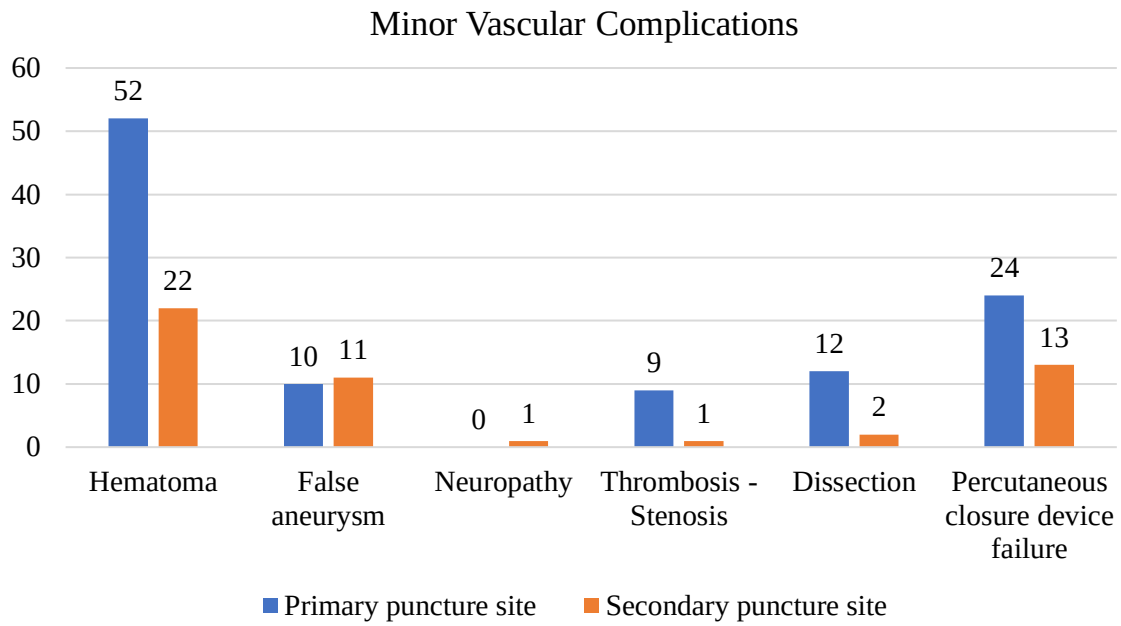


Figure 2

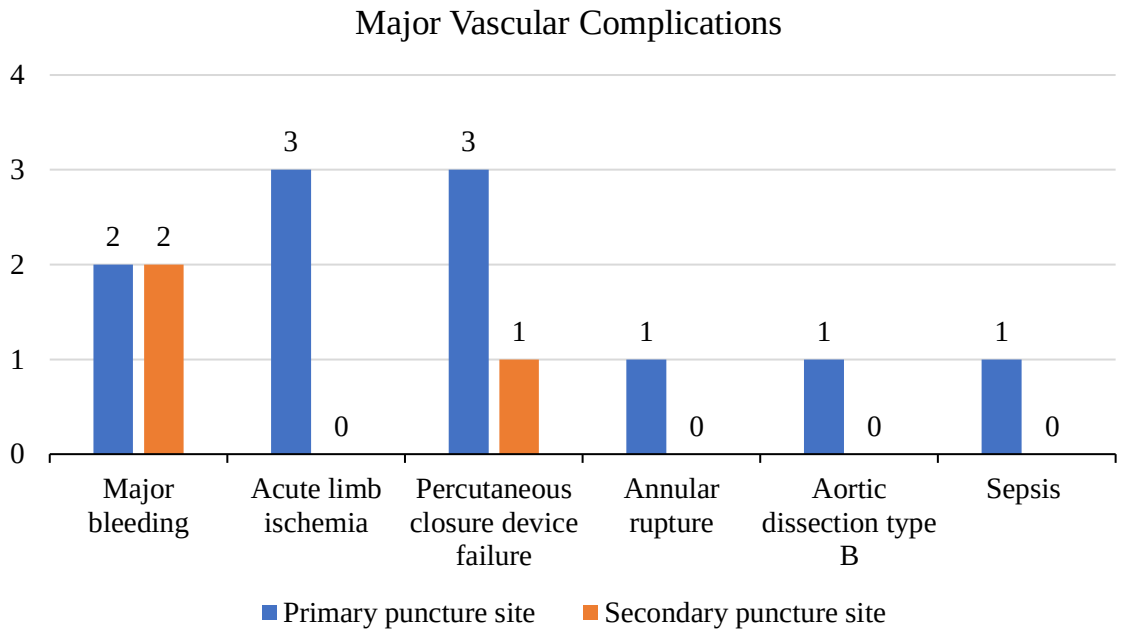
Minor Vascular Complications



Distribution of minor VCs according to the arterial puncture point, 157 events are reported for 111 patients, 46 patients cumulated two minor VCs.

Figure 3

Major Vascular Complications.



Distribution of major VCs according to the arterial puncture point, 14 events are reported for 14 patients.

Figure 4

Sensibility/Specificity curves for prediction of all vascular complications (minor and major) by SIFAR.

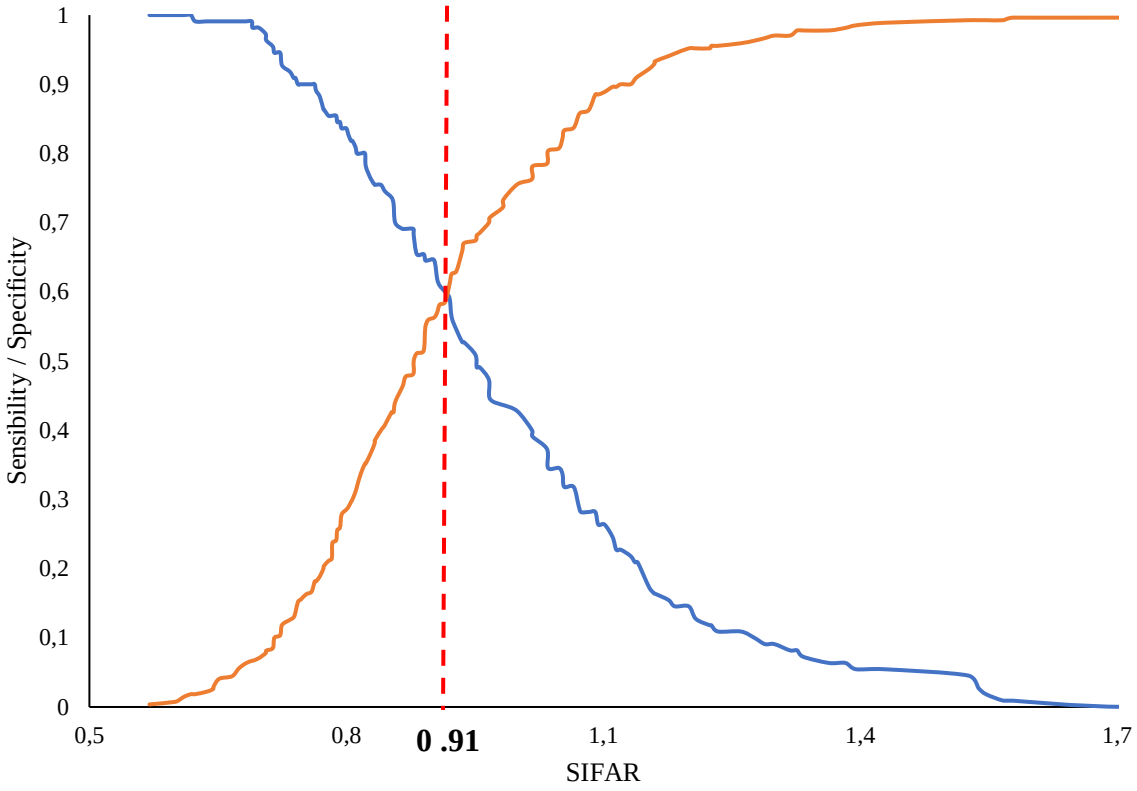


Figure 5

Sensibility/Specificity curves for prediction of major vascular complications by SIFAR.

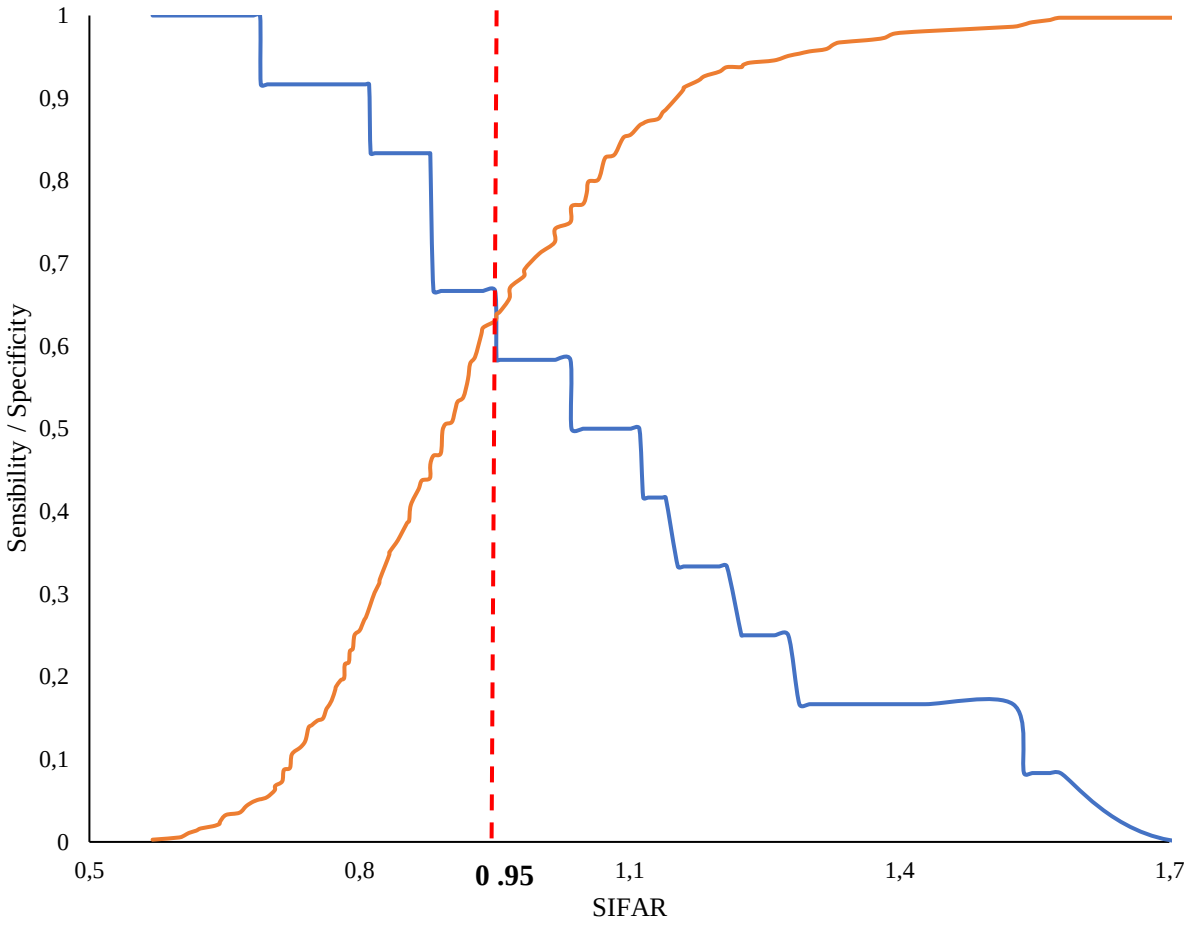


Figure 6

Sensibility/Specificity curves for prediction of all vascular complications (minor and major) by minimal iliofemoral diameter

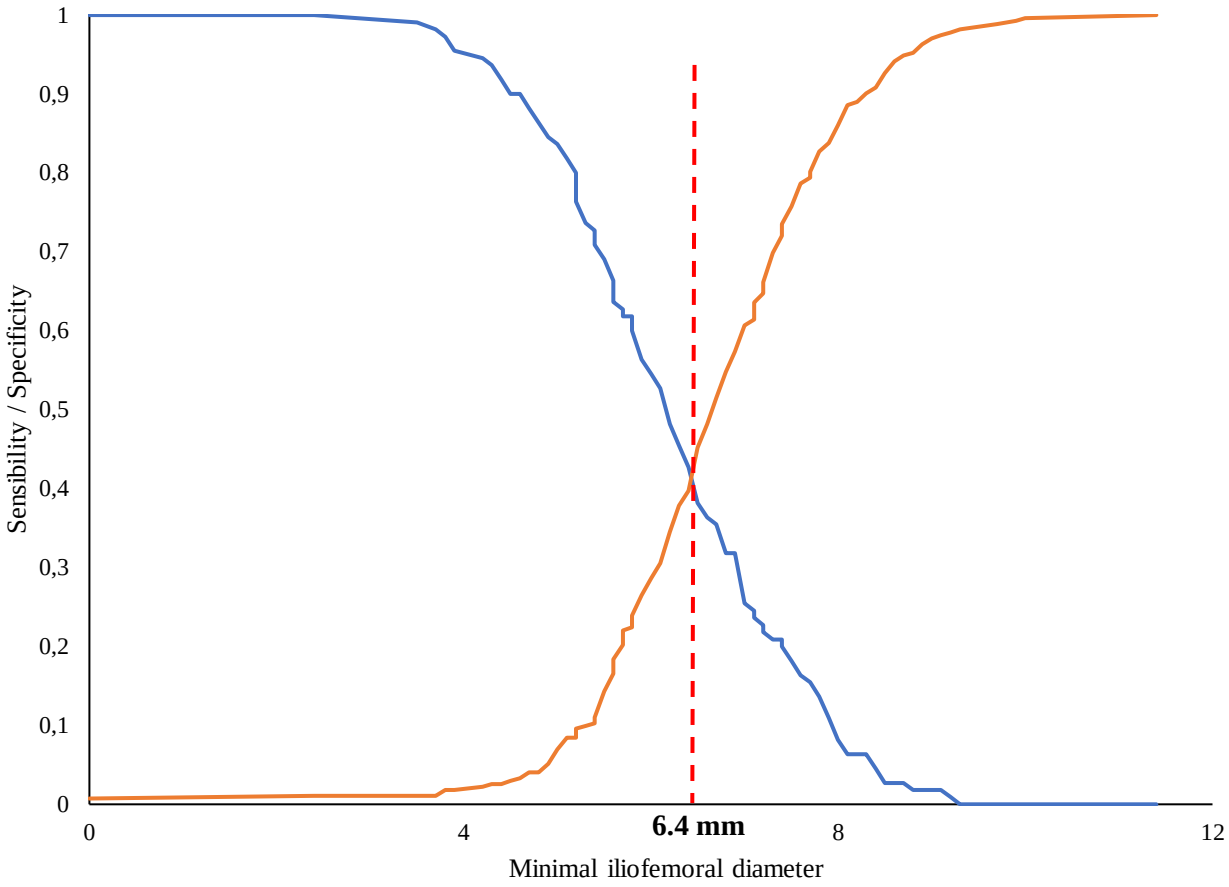


Figure 7

Sensibility/Specificity curves for prediction of major vascular complications by minimal iliofemoral diameter.

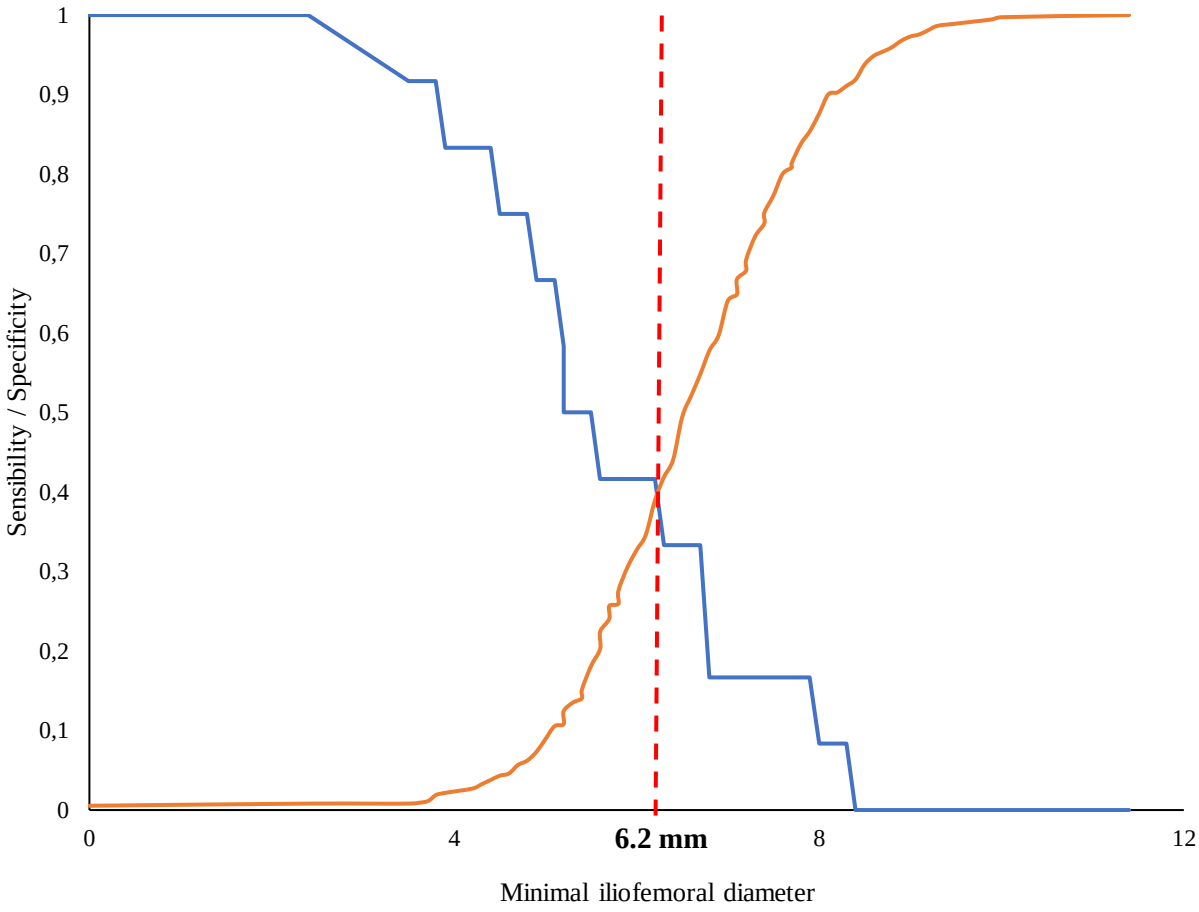
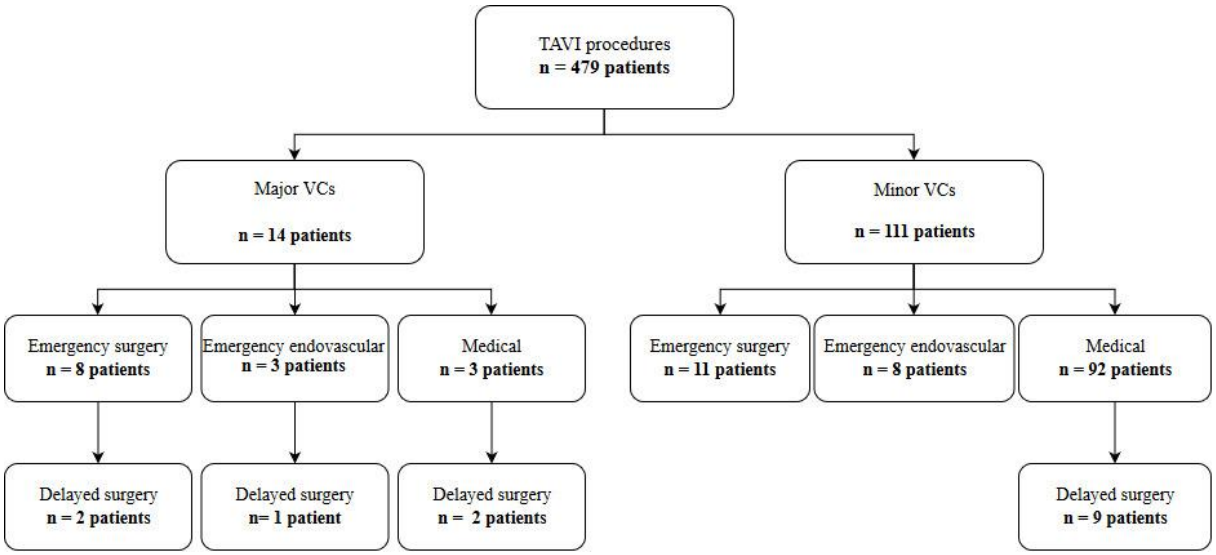


Figure 8

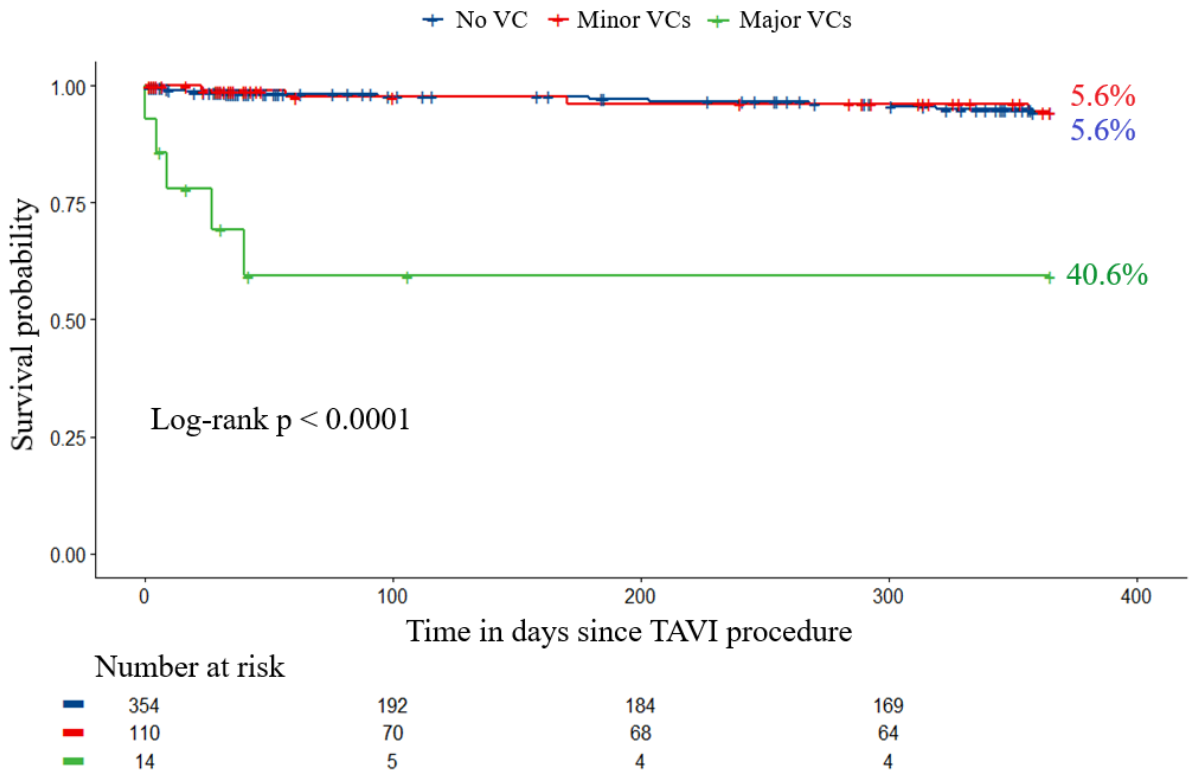
Treatment distribution of vascular complications.



Forty-one patients underwent vascular surgery, 30 emergent vascular surgery and 14 delayed vascular surgery. Three patients needed two interventions.

Figure 9

Kaplan-Meier curves of survival probability at 1-year follow-up after TAVI procedure.



Numbers at risk are the cumulative incidence at each landmark point. Percentages are the cumulative incidence of death at 1-year follow-up for each group.

Tables:

Table 1

Preoperative characteristics aggregate to vascular complications

Characteristics	Vascular complications			
	No VC n = 340	**Minor VC n = 111**	**Major VC n = 14**	**p-value**
Age (years)	82.6 ± 6.5	83.4 ± 6.0	82.2 ± 5.7	0.283
Women	156 (45.9%)	53 (47.7%)	9 (64,3%)	0.286
Body Mass Index (kg/m²)	27 ± 5	26.7 ±7.1	24± 4.6	0.184
Medical history				
Hypertension	295 (84.3%)	86 (77.5%)	13 (92,9%)	0.194
Diabetes all types	98 (27.9%)	28 (25.2%)	3 (21,4%)	0.500
Dyslipidemia	204 (58.1%)	65 (58.6%)	3 (21.4%)	0.471
History of smoke	78 (22.3%)	22 (20%)	2 (14.3%)	0.495
Chronic obstructive pulmonary disease	63 (17.9%)	25 (22.5%)	5 (35.7%)	0.143
Cirrhosis	8 (2,3%)	2 (1.8%)	0	0.649
History of neoplasia	64 (18.2%)	18 (16.2%)	2 (14.3%)	0.574
Chronic renal failure [a]	136 (38.9%)	46 (41.4%)	5 (35.7%)	0.703
Ischemic heart disease	127 (36.3%)	39 (35.1%)	4 (28.6%)	0.706
Coronary bypass	24 (6.9%)	11 (10%)	0	0.461
Valvular heart surgery	15 (4.3%)	8 (7.2%)	0	0.345
Percutaneous aortic valvuloplasty	10 (2.9%)	7 (6.4%)	0	0.153
Percutaneous coronary intervention [b]	82 (23.6%)	31 (28.2%)	3 (21.4%)	0.135
Permanent pacemaker	29 (8.2%)	20 (18%)	0	0.014
Permanent atrial fibrillation	105 (29.8%)	42 (37.8%)	6 (42.9%)	0.078
NYHA class III or IV	173 (49.3%)	57 (51.8%)	9 (64.3%)	0.451
Acute pulmonary edema	84 (24.1%)	29 (26.4%)	5 (35.7%)	0.499
Chronic cardiac angina	46 (13.1%)	20 (18.2%)	2 (14.3%)	0.209
Pulmonary arterial hypertension moderate/severe	149 (46%)	50 (47.2%)	5 (41.7%)	0.908
History of stroke	30 (8.6%)	8 (7.2%)	2 (14.3%)	0.843
MMSE <27	14 (4%)	5 (4.5%)	2 (14.3%)	0.451
Logistic EuroSCORE	15.2 ± 11	16.4 ± 12.1	13.4 ± 9.6	0.457
STS-PROM score	4.6 ± 2.3	4.3 ± 1.9	6.8 ± 3.7	0.654
Peripheral vascular disease	44 (13.3%)	16 (16%)	1 (7.7%)	0.149
Echocardiography				
Left ventricular ejection fraction (%)	56.8 ± 0.7	57.8 ± 1.3	52.7 ± 3.8	0.759
Aortic valve area (cm²)	0.73 ± 0.01	0.77 ± 0.02	0.64 ± 0.05	0.175

Biology at baseline				
Hemoglobin level (g/dL)	12.5 ± 0.1	12.6 ± 0.2	12.1 ± 0.6	0.813
Platelets (G/L)	217.7 ± 3.9	203.9 ± 7.2	275 ± 20.6	0.432
Prothrombin time (%)	83 ± 1.2	83.8 ± 2.3	77.3 ± 6	0.967
Creatinine (µmol/L)	107.6 ± 2.7	110.9 ± 5	107.6 ± 2.7	0.191
Preoperative treatment				
Anticoagulant	104 (29.4%)	41 (37%)	5 (35.7%)	0.124
Antiplatelet monotherapy	138 (39%)	40 (36%)	3 (21.4%)	0.364
Antiplatelet bitherapy	46 (13%)	15 (13.5%)	2 (14.3%)	0.863
Oral direct anticoagulants use (OADs)	47 (13.3%)	15 (13.5%)	1(7.2%)	0.892

p-values are for comparison in two groups: without VCs and with VCs.

STS-PROM = Society of Thoracic Surgery predicted risk of mortality; NYHA = New York Heart Association; MMSE = Mini-Mental State Evaluation

[a] Glomerular filtration rate < 60ml/min

[b] Including only angioplasty and/or coronary stenting

Table 2

Procedural and CT- angiography characteristics agregate to vascular complications

Characteristics	Vascular complication			
	No VC n = 354	**Minor VC n = 111**	**Major VC n = 14**	**p-value**
Urgent procedure	19 (5.4%)	2 (1.8)	3 (21.4)	0.547
Local anesthesia	314 (88.9%)	98 (88.3%)	8 (57.1%)	0.222
Conversion to general anesthesia	1 (0.3%)	6 (1.3%)	5 (35.7%)	<0.001
Technical success	347 (98.2%)	109 (98.2%)	14 (100%)	1
True femoral percutaneous	300 (84.7%)	103 (92.8%)	13 (92.9%)	0.034
Radial secondary puncture	112 (32.5%)	25 (22.7%)	1 (7.2%)	0.016
Valve type				0.864
CoreValve EVOLUTR	134 (37.9%)	46 (41.4%)	7 (50%)	
23mm	14 (%)	6 (5.4%)	1 (7.1%)	
26mm	58 (16.4%)	23 (20.7%)	2 (14.3%)	
29mm	57 (15.2%)	17 (15.3%)	4 (28.6%)	
31mm	1 (0.3%)	0	0	
34mm	4 (1.1%)	0	0	
Edward SAPIEN 3	215 (60.7%)	64 (57.6%)	7 (50%)	
23mm	74 (20.9%)	26 (23.4%)	3 (21.4%)	
26mm	100 (28.2%)	26 (23.4%)	2 (14.3%)	
29mm	41 (11.6%)	2 (1.8%)	2 (14.3%)	
Portico	3 (0.9%)	0	0	
23mm	1 (0.3%)	0	0	
25mm	1 (0.3%)	0	0	
29mm	1 (0.3%)	0	0	
Minimal iliofemoral diameter (mm)	6.7 ± 1.3	6.3 ± 1.2	5.8 ± 1.5	0.002
Sheath-to-iliofemoral ratio	0.91 ± 0.2	0.98 ± 0.2	1.1 ± 0.3	<0.001
Primary puncture closure device				0.07
Perclose Proglide	133 (37.6%)	42 (37.8%)	6 (42.9%)	
Prostar	158 (44.6%)	60 (54%)	7 (50%)	
Secondary puncture closure device				0.642
Femoseal	191 (54%)	62 (55.8%)	12 (85.7%)	
Manual compression	117 (33%)	40 (36%)	2 (14.3%)	
Others systems	24 (6.7%)	6 (5.4%)	0	
Irradiation time (mn)	14.9 ± 7	15.1 ± 8.3	19.2 ± 10.3	0.444
AirKerma (mGy)	276.7 ± 120.3	330.9 ± 218.2	409.3 ± 368.5	0.470

PDS total (cGy.m²)	3967.1 ± 2910	4078.5 ± 2894.5	4616.2 ± 3976.6	0.170
Contrast volume (mL)	104.3 ± 48.9	97.6 ± 37.3	102.9 ± 49.8	0.239

Closure device primary puncture was missing in 14 patients
Closure device secondary puncture was missing in 25 patients

Table 3

Predictors of all vascular complications in multivariate analysis

	Adjusted OR (95% CI)	**p-value**
Age	1.02 (0.99-1.06)	0.221
Female	1.16 (0.76-1.78)	0.497
BMI	0.99 (0.95-1.03)	0.662
Diabetes	0.87 (0.54-1.42)	0.579
Peripheral artery disease	0.87(0.53-1.42)	0.528
Chronic renal failure	1.12 (0.72-1.72)	0.628
Logistic Euroscore	1.01 (0.99-1.03)	0.355
Anticoagulant use	1.41 (0.90-2.20)	0.135
OADs use	1.02 (0.55-1.91)	0.949
Femoral secondary puncture	0.61 (0.37-1.01)	0.054
IMS score	1.25 (1.08-1.46)	**0.003**
SIFAR	6.52 (1.19-21.34)	**0.002**
Moderate/severe calcification	2.00 (1.29-3.10)	**0.002**
Moderate/severe tortuosity	2.36 (1.48-3.76)	**<0.001**

Table 4

Predictors of major vascular complications in multivariate analysis

	Adjusted OR (95% CI)	**p-value**
Age	0.99 (0.92-1.07)	0.835
Female	2.29 (0.75-6.95)	0.146
BMI	0.87 (0.76-0.99)	**0.040**
Diabetes	0.70 (0.19-2.58)	0.596
Peripheral artery disease	1.64(0.36-7.49)	0.523
Chronic renal failure	0.87 (0.29-2.66)	0.813
Logistic Euroscore	0.98 (0.92-1.05)	0.611
Anticoagulant use	1.34 (0.44-4.08)	0.612
OADs use	0.50 (0.06-3.93)	0.512
Femoral secondary puncture	0.16 (0.02-1.24)	0.079
IMS score	1.33 (0.92-1.91)	0.134
SIFAR	31.02 (4.03-238.61)	**0.001**
Moderate/severe calcification	0.32 (0.09-1.17)	0.084
Moderate/severe tortuosity	1.57 (0.52-4.78)	0.426

Table 5

Emergency vascular surgery (endovascular or open) during TAVI procedure for vascular complications

	Access	Percutaneous closure device	Complications	VARC	Treatment	Outcome at 1-year
1	Primary	Perclose-Proglide	Closure device failure	Minor	Surgical closure	Alive
2	Primary	Perclose Proglide	Arterial perforation with closure device failure	Minor	Surgical closure	Alive
3*	Primary	Prostar	Acute limb ischemia by iliofemoral complete thrombosis	Major	Femoral endarterectomy with iliac stenting	Death
4	Primary	Perclose Proglide	Closure device failure	Minor	Iliofemoral covered stenting	Alive
5	Primary	Prostar	Closure device failure	Minor	Iliofemoral covered stenting	Alive
6	Primary	Prostar	Iliofemoral dissection with perforation	Minor	External iliac covered stenting	Alive
7	Primary	Prostar	Closure device failure	Minor	Iliofemoral covered stenting	Alive
8	Primary	Prostar	Iliofemoral dissection	Minor	Iliofemoral covered stenting	Death
9	Primary	Perclose Proglide	Closure device failure	Minor	Iliofemoral covered stenting	Alive
10	Primary	Prostar	Acute limb ischemia	Major	Thromboaspiration and stenting	Death
11*	Primary	Perclose Proglide	Acute limb ischemia	Major	Thromboaspiration and stenting	Alive
12	Primary	Perclose Proglide	Closure device failure	Minor	Surgical closure	Alive
13	Primary	Prostar	Closure device failure	Minor	Surgical closure	Alive

14	Primary	Perclose Proglide	Closure device failure	Minor	Surgical closure	Alive
15	Primary	Perclose Proglide	Common femoral perforation	Major	Surgical closure	Alive
16	Primary	Prostar	Closure device failure	Major	Surgical closure	Death
17	Primary	Perclose Proglide	Closure device failure	Major	Iliofemoral covered stenting	Alive
18*	Secondary	Femoseal	Arterial perforation	Major	Surgical closure	Alive
19	Primary	Perclose Proglide	Closure device failure	Minor	Surgical closure	Alive
20	Primary	Perclose Proglide	Arterial perforation	Major	Surgical closure	Death
21	Primary	Perclose Proglide	Femoral thrombosis	Major	Iliofemoral endarterectomy	Alive
22	Secondary	Femoseal	Major bleeding	Major	Surgical closure	Alive
23	Primary	Perclose Proglide	Arterial dissection	Minor	Surgical repair	Alive
24	Primary	Prostar	Iliac dissection	Minor	Non covered iliac stenting	Alive
25	Secondary	Femoseal	Large volume hematoma	Minor	Evacuation - drainage	Death
26	Primary	Prostar	Closure device failure	Minor	Surgical closure	Alive
27	Primary	Perclose Proglide	Closure device failure	Minor	Surgical closure	Alive
28	Primary	Perclose Proglide	Femoral dissection	Minor	Non covered iliofemoral stenting	Alive
29	Secondary	Angioseal	Closure device failure	Major	Surgical closure	Alive
30	Primary	Prostar	Ilio-femoral perforation	Minor	Surgical closure	Alive

*3 patients had a second intervention described in Table 6

Table 6

Delayed surgical reintervention after TAVI procedure

	Access	Percutaneous closure device	Complications	VARC	Treatment	Days after TAVI	Outcome at 1-year
1*	Primary	Perclose-Proglide	Acute limb ischemia	Major	Axillo-femoral by pass	5	Death
2	Primary	Subclavian	Bleeding - Hematoma	Minor	Evacuation - drainage	6	Alive
3	Primary	Perclose-Proglide	False aneurysm	Major	Surgical closure	4	Alive
4	Primary	Perclose-Proglide	False aneurysm	Minor	Surgical closure	3	Alive
5*	Secondary	Femoseal	Distal embolization	Major	Toes amputation	30	Death
6	Secondary	Femoseal	False aneurysm	Minor	Surgical closure	5	Alive
7	Secondary	Femoseal	False aneurysm	Minor	Surgical closure	7	Alive
8*	Primary	Prostar	Acute limb ischemia	Major	Transfemoral amputation	2	Death
9	Primary	Prostar	False aneurysm	Minor	Surgical closure	2	Alive
10	Primary	Prostar	Infected hematoma	Minor	Evacuation - drainage	9	Alive
11	Primary	Prostar	Infected hematoma	Minor	Evacuation - drainage	6	Alive
12	Secondary	Femoseal	False aneurysm and arterio-venous fistula	Minor	Surgical closure	14	Alive
13	Primary	Subclavian	Bleeding – Hematoma	Minor	Hemostasis – drainage	1	Alive
14	Primary	Transaortic	Mediastinitis	Major	Surgical drainage	29	Alive

*3 patients had a first intervention before that described in Table 5

Table 7

In-hospital outcomes for every three groups.

	Vascular complications			
	No VC n = 354	**Minor VC n = 111**	**Major VC n = 14**	**p-value**
Bleeding				
Major/Life threatening	2 (0.6%)	0	6 (42.8%)	**0.001**
Minor	8 (2.3%)	50 (14.1%)	2 (14.3%)	**<0.001**
Decrease haemoglobin (g/dL)	0.69 ± 0.87	0.91 ± 0.91	1.67 ± 1.07	**0.003**
Transfusion [a]	0.01 ± 0.2	0.06 ± 0.31	0.69 ± 1.2	**<0.001**
Stroke				
Dislabing	3 (0.8%)	1 (0.9%)	4 (28.6%)	**0.018**
Non-dislabing	0	2 (1.8%)	1 (7.1%)	**0.003**
Acute Kidney Injury [b]	4 (1.12%)	1 (0.9%)	0	0.76
Myocardial infarction	3 (0.85%)	1 (0.9%)	3 (21.4%)	0.06
Delayed surgery	3 (0.85%)	9 (8.1%)	5 (35.7%)	**<0.001**
Length of hospital stay				
ICU (days) [c]	0.9 ± 1.57	1.2 ± 1.89	2.8 ± 3.98	**0.013**
LOS (days) [d]	6.5 ± 3.8	6.8 ± 3.43	14.6 ± 8.21	**0.004**

[a] In number of units of packed cells transfused

[b] Acute Kidney Injury stage 2 and 3 were included according to AKIN classification

[c] Length of stay in the intensive care unit

[d] Total length of hospital stay

p-values are for comparison in two groups: without VCs and with VCs.

Definitions of bleeding, stroke, acute kidney injury, myocardial infarction are according to VARC-2 definitions (8,40).

Table 8

Univariate and multivariate analysis with hazard ratio of survival curves at one year.

1-year survival	**Univariate model**		**Multivariate model**	
	Unadjusted HR (95% CI)	**p-value**	**Adjusted HR (95% CI)**	**p-value**
Minor VC	0.69(0.23-2.04)	p=0.49	0.91(0.28-2.93)	p = 0.87
Major VC	14.19(5.17-38.94)	p<0 .001	18.69(5.72-61.13)	p<0.0001

Adjustment for multivariate model was covariates with p-values < 0.20: body mass index, hypertension, permanent atrial fibrillation, peripheral vascular disease, valvuloplasty, pacemaker, chronic obstructive pulmonary disease, creatinine level, anticoagulant therapy.

References:

1. Leon MB, Smith CR, Mack M, Miller DC, Moses JW, Svensson LG, et al. Transcatheter Aortic-Valve Implantation for Aortic Stenosis in Patients Who Cannot Undergo Surgery. N Engl J Med. 2010 Oct 21;363(17):1597–607.

2. Leon MB, Smith CR, Mack MJ, Makkar RR, Svensson LG, Kodali SK, et al. Transcatheter or Surgical Aortic-Valve Replacement in Intermediate-Risk Patients. N Engl J Med. 2016 28;374(17):1609–20.

3. Mylotte D, Osnabrugge RLJ, Windecker S, Lefèvre T, de Jaegere P, Jeger R, et al. Transcatheter aortic valve replacement in Europe: adoption trends and factors influencing device utilization. J Am Coll Cardiol. 2013 Jul 16;62(3):210–9.

4. 2017 ESC/EACTS Guidelines for the management of valvular heart disease | European Heart Journal | Oxford Academic 2018 Nov 26.

5. Généreux P, Webb JG, Svensson LG, Kodali SK, Satler LF, Fearon WF, et al. Vascular complications after transcatheter aortic valve replacement: insights from the PARTNER (Placement of AoRTic TraNscathetER Valve) trial. J Am Coll Cardiol. 2012 Sep 18;60(12):1043–52.

6. van Kesteren F, van Mourik MS, Vendrik J, Wiegerinck EMA, Henriques JPS, Koch KT, et al. Incidence, Predictors, and Impact of Vascular Complications After Transfemoral Transcatheter Aortic Valve Implantation With the SAPIEN 3 Prosthesis. Am J Cardiol. 2018 May 15;121(10):1231–8.

7. Kazuaki O, Hasan J, Yigal A, Mohammad K, Jigar P, Heera P, et al. The clinical impact of vascular complications as defined by VARC-1 vs. VARC-2 in patients following transcatheter aortic valve implantation. Eurointervention J. 2016 Aug 5.

8. Kappetein AP, Head SJ, Généreux P, Piazza N, van Mieghem NM, Blackstone EH, et al. Updated standardized endpoint definitions for transcatheter aortic valve implantation: the Valve Academic Research Consortium-2 consensus document (VARC-2). Eur J Cardio-Thorac Surg Off J Eur Assoc Cardio-Thorac Surg. 2012 Nov;42(5):S45-60.

9. Généreux P, Head SJ, Wood DA, Kodali SK, Williams MR, Paradis J-M, et al. Transcatheter aortic valve implantation: 10-year anniversary. Part II: clinical implications. Eur Heart J. 2012 Oct 1;33(19):2399–402.

10. Gilard M, Eltchaninoff H, Donzeau-Gouge P, Chevreul K, Fajadet J, Leprince P, et al. Late Outcomes of Transcatheter Aortic Valve Replacement in High-Risk Patients: The FRANCE-2 Registry. J Am Coll Cardiol. 2016 11;68(15):1637–47.

11. Koehler T, Buege M, Schleiting H, Seyfarth M, Tiroch K, Vorpahl M. Changes of the eSheath Outer Dimensions Used for Transfemoral Transcatheter Aortic Valve Replacement. BioMed Research International. 2015

12. Manoharan G, Walton AS, Brecker SJ, Pasupati S, Blackman DJ, Qiao H, et al. Treatment of Symptomatic Severe Aortic Stenosis With a Novel Resheathable Supra-Annular Self-Expanding Transcatheter Aortic Valve System. JACC Cardiovasc Interv. 2015 Aug 24;8(10):1359–67.

13. Sorropago G, Auguadro C, Sorropago A, Finizio M, Scalise F. Sheathless Use of the New Portico™ Transcatheter Aortic Valve System in Complex Vascular Access Cases. :3.

14. Cribier A, Eltchaninoff H, Bash A, Borenstein N, Tron C, Bauer F, et al. Percutaneous transcatheter implantation of an aortic valve prosthesis for calcific aortic stenosis: first human case description. Circulation. 2002 Dec 10;106(24):3006–8.

15. Kodali SK, Williams MR, Smith CR, Svensson LG, Webb JG, Makkar RR, et al. Two-year outcomes after transcatheter or surgical aortic-valve replacement. N Engl J Med. 2012 May 3;366(18):1686–95.

16. Blakeslee-Carter J, Dexter D, Mahoney P, Ahanchi S, Steerman S, Larion S, et al. A Novel Iliac Morphology Score Predicts Procedural Mortality and Major Vascular Complications in Transfemoral Aortic Valve Replacement. Ann Vasc Surg. 2018 Jan;46:208–17.

17. Taudorf M, Jensen LP, Vogt KC, Grønvall J, Schroeder TV, Lönn L. Endograft limb occlusion in EVAR: iliac tortuosity quantified by three different indices on the basis of preoperative CTA. Eur J Vasc Endovasc Surg Off J Eur Soc Vasc Surg. 2014 Nov;48(5):527–33.

18. Zhang S, Kolominsky-Rabas PL. How TAVI registries report clinical outcomes—A systematic review of endpoints based on VARC-2 definitions. PLOS ONE. 2017 Sep 14;12(9):e0180815.

19. Holmes DR, Nishimura RA, Grover FL, Brindis RG, Carroll JD, Edwards FH, et al. Annual Outcomes With Transcatheter Valve Therapy: From the STS/ACC TVT Registry. J Am Coll Cardiol. 2015 Dec 29;66(25):2813–23.

20. Elbaz-Greener G, Zivkovic N, Arbel Y, Radhakrishnan S, Fremes SE, Wijeysundera HC. Use of Two-Dimensional Ultrasonographically Guided Access to Reduce Access-Related Complications for Transcatheter Aortic Valve Replacement. Can J Cardiol. 2017;33(7):918–24.

21. Hayashida K, Lefèvre T, Chevalier B, Hovasse T, Romano M, Garot P, et al. Transfemoral aortic valve implantation new criteria to predict vascular complications. JACC Cardiovasc Interv. 2011 Aug;4(8):851–8.

22. Czerwińska-Jelonkiewicz K, Michałowska I, Witkowski A, Dąbrowski M, Księżycka-Majczyńska E, Chmielak Z, et al. Vascular complications after transcatheter aortic valve implantation (TAVI): risk and long-term results. J Thromb Thrombolysis. 2014 May;37(4):490–8.

23. Steinvil A, Leshem-Rubinow E, Halkin A, Abramowitz Y, Ben-Assa E, Shacham Y, et al. Vascular Complications After Transcatheter Aortic Valve Implantation and Their Association With Mortality Reevaluated by the Valve Academic Research Consortium Definitions. Am J Cardiol. 2015 Jan 1;115(1):100–6.

24. Mwipatayi BP, Picardo A, Masilonyane-Jones TV, Larbalestier R, Thomas S, Turner J, et al. Incidence and prognosis of vascular complications after transcatheter aortic valve implantation. J Vasc Surg. 2013 Oct;58(4):1028-1036.e1.

25. Uguz E, Gokcimen M, Ali S, Alsancak Y, Bastug S, Ahmet Kasapkara H, et al. Predictability and Outcome of Vascular Complications after Transfemoral Transcatheter Aortic Valve Implantation. J Heart Valve Dis. 2016;25(2):173–81.

26. Holmes DR, Mack MJ, Kaul S, Agnihotri A, Alexander KP, Bailey SR, et al. 2012 ACCF/AATS/SCAI/STS expert consensus document on transcatheter aortic valve replacement. J Am Coll Cardiol. 2012 Mar 27;59(13):1200–54.

27. Daneault B, Kirtane AJ, Kodali SK, Williams MR, Genereux P, Reiss GR, et al. Stroke associated with surgical and transcatheter treatment of aortic stenosis: a comprehensive review. J Am Coll Cardiol. 2011 Nov 15;58(21):2143–50.

28. Van Mieghem NM, Tchetche D, Chieffo A, Dumonteil N, Messika-Zeitoun D, van der Boon RMA, et al. Incidence, predictors, and implications of access site complications with transfemoral transcatheter aortic valve implantation. Am J Cardiol. 2012 Nov 1;110(9):1361–7.

29. Masson J-B, Kovac J, Schuler G, Ye J, Cheung A, Kapadia S, et al. Transcatheter aortic valve implantation: review of the nature, management, and avoidance of procedural complications. JACC Cardiovasc Interv. 2009 Sep;2(9):811–20.

30. Beve M, Auffret V, Belhaj Soulami R, Tomasi J, Anselmi A, Roisne A, et al. Comparison of the Transarterial and Transthoracic Approaches in Nontransfemoral Transcatheter Aortic Valve Implantation. Am J Cardiol. 2019 May 1;123(9):1501–9.

31. Gleason TG, Schindler JT, Hagberg RC, Deeb GM, Adams DH, Conte JV, et al. Subclavian/Axillary Access for Self-Expanding Transcatheter Aortic Valve Replacement Renders Equivalent Outcomes as Transfemoral. Ann Thorac Surg. 2018 Feb;105(2):477–83.

32. Hernández-Enriquez M, Andrea R, Brugaletta S, Jiménez-Quevedo P, Hernández-García JM, Trillo R, et al. Puncture Versus Surgical Cutdown Complications of Transfemoral Aortic Valve Implantation (from the Spanish TAVI Registry). Am J Cardiol. 2016 Aug 15;118(4):578–84.

33. Abdel-Wahab M, Mehilli J, Frerker C, Neumann F-J, Kurz T, Tölg R, et al. Comparison of balloon-expandable vs self-expandable valves in patients undergoing transcatheter aortic valve replacement: the CHOICE randomized clinical trial. JAMA. 2014 Apr 16;311(15):1503–14.

34. Tchetche D, Dumonteil N, Sauguet A, Descoutures F, Luz A, Garcia O, et al. Thirty-day outcome and vascular complications after transarterial aortic valve implantation using both Edwards Sapien and Medtronic CoreValve bioprostheses in a mixed population. EuroIntervention J Eur Collab Work Group Interv Cardiol Eur Soc Cardiol. 2010 Jan;5(6):659–65.

35. Chieffo A, Buchanan GL, Van Mieghem NM, Tchetche D, Dumonteil N, Latib A, et al. Transcatheter aortic valve implantation with the Edwards SAPIEN versus the Medtronic CoreValve Revalving system devices: a multicenter collaborative study: the PRAGMATIC Plus Initiative (Pooled-RotterdAm-Milano-Toulouse In Collaboration). J Am Coll Cardiol. 2013 Feb 26;61(8):830–6.

36. Barbash IM, Barbanti M, Webb J, Molina-Martin De Nicolas J, Abramowitz Y, Latib A, et al. Comparison of vascular closure devices for access site closure after transfemoral aortic valve implantation. Eur Heart J. 2015 Dec 14;36(47):3370–9.

37. Dimitriadis Z, Scholtz W, Börgermann J, Wiemer M, Piper C, Vlachojannis M, et al. Impact of closure devices on vascular complication and mortality rates in TAVI procedures. Int J Cardiol. 2017 Aug 15;241:133–7.

38. Seeger J, Gonska B, Rodewald C, Rottbauer W, Wöhrle J. Impact of suture mediated femoral access site closure with the Prostar XL compared to the ProGlide system on outcome in transfemoral aortic valve implantation. Int J Cardiol. 2016 Nov 15;223:564–7.

39. Moore CL. Ultrasound first, second, and last for vascular access. J Ultrasound Med Off J Am Inst Ultrasound Med. 2014 Jul;33(7):1135–42.

40. Kappetein AP, Head SJ, Généreux P, Piazza N, van Mieghem NM, Blackstone EH, et al. Updated standardized endpoint definitions for transcatheter aortic valve implantation: the Valve Academic Research Consortium-2 consensus document. J Thorac Cardiovasc Surg. 2013 Jan;145(1):6–23.

Supplementary Table:

Supplementary Table 1

Vascular complications according to VARC-2 consortium definitions.

Table 2. Vascular access site and access-related complications

Major vascular complications

- Any aortic dissection, aortic rupture, annulus rupture, left ventricle perforation or new apical aneurysm/pseudoaneurysm.
- Access site or access-related vascular injury (dissection, stenosis, perforation, rupture, arteriovenous fistula, pseudoaneurysm, haematoma, irreversible nerve injury, compartment syndrome and/or percutaneous closure device failure) leading to death, life-threatening or major bleeding,* visceral ischaemia or neurological impairment.
- Distal embolization (noncerebral) from a vascular source requiring surgery or resulting in amputation or irreversible end-organ damage.
- Use of unplanned endovascular or surgical intervention associated with death, major bleeding, visceral ischaemia or neurological impairment.
- Any new ipsilateral lower extremity ischaemia documented by patient symptoms, physical exam and/or decreased or absent blood flow on lower extremity angiogram.
- Surgery for access site-related nerve injury.
- Permanent access site-related nerve injury.

Minor vascular complications

- Access site or access-related vascular injury (dissection, stenosis, perforation, rupture, arteriovenous fistula, pseudoaneuysms, haematomas and/or percutaneous closure device failure) not leading to death, life-threatening or major bleeding, visceral ischaemia or neurological impairment.
- Distal embolization treated with embolectomy and/or thrombectomy and not resulting in amputation or irreversible end-organ damage.
- Any unplanned endovascular stenting or unplanned surgical intervention not meeting the criteria for a major vascular complication.
- Vascular repair or the need for vascular repair (via surgery, ultrasoundguided compression, transcatheter embolization or stent-graft).

Percutaneous closure device failure

- Failure of a closure device to achieve haemostasis at the arteriotomy site leading to alternative treatment (other than manual compression or adjunctive endovascular ballooning).

Supplementary Table 2:

Bleeding definitions according to VARC-2 consortium.

TABLE 5. Bleeding

Life-threatening or disabling bleeding
Fatal bleeding *(BARC type 5)* OR
Bleeding in a critical organ, such as intracranial, intraspinal, intraocular, or pericardial necessitating pericardiocentesis, or intramuscular with compartment syndrome *(BARC type 3b and 3c)* OR
Bleeding causing hypovolemic shock or severe hypotension requiring vasopressors or surgery *(BARC type 3b)* OR
Overt source of bleeding with drop in hemoglobin ≥5 g/dL or whole blood or packed red blood cells (RBCs) transfusion ≥4 units* *(BARC type 3b)*
Major bleeding *(BARC type 3a)*
Overt bleeding either associated with a drop in the hemoglobin level of at least 3.0 g/dL or requiring transfusion of 2 or 3 units of whole blood/RBC, or causing hospitalization or permanent injury, or requiring surgery AND
Does not meet criteria of life-threatening or disabling bleeding
Minor bleeding (*BARC type 2 or 3a, depending on the severity)*
Any bleeding worthy of clinical mention (eg, access site hematoma) that does not qualify as life-threatening, disabling, or major

BARC, Bleeding Academic Research Consortium[29]; *RBC*, red blood cell. *Given that 1 *unit* of packed RBC typically will raise the hemoglobin concentration by 1 g/dL, an estimated decrease in hemoglobin will be calculated.

Supplementary Table 3 :

Acute Kidney Injury defintions according to VARC-2 consortium.

TABLE 6. Acute kidney injury (AKIN classification*)

Stage 1
Increase in serum creatinine to 150%-199% (1.5-1.99 × increase compared with baseline) OR increase of ≥0.3 mg/dL (≥26.4 mmol/L) OR
Urine output <0.5 mL/kg/h for >6 but <12 h
Stage 2
Increase in serum creatinine to 200%-299% (2.0%-2.99% increase compared with baseline) OR
Urine output <0.5 mL/kg/h for >12 but <24 h
Stage 3†
Increase in serum creatinine to ≥300% (>3 × increase compared with baseline) OR serum creatinine of ≥4.0 mg/dL (≥354 mmol/L) with an acute increase of at least 0.5 mg/dL (44 mmol/L) OR
Urine output <0.3 ml/kg/h for ≥24 h OR
Anuria for ≥12 h

The increase in creatinine must occur within 48 h. *Mehta et al.[31] †Patients receiving renal replacement therapy are considered to meet Stage 3 criteria irrespective of other criteria.

Supplementary Table 4 :

Stroke and TIA definitions according to VARC-2 consortium.

TABLE 4. Stroke and TIA

Diagnostic criteria
Acute episode of a focal or global neurological deficit with at least 1 of the following: change in the level of consciousness, hemiplegia, hemiparesis, numbness, or sensory loss affecting 1 side of the body, dysphasia or aphasia, hemianopia, amaurosis fugax, or other neurological signs or symptoms consistent with stroke
Stroke: duration of a focal or global neurological deficit ≥24 h; OR <24 h if available neuroimaging documents a new hemorrhage or infarct; OR the neurological deficit results in death
TIA: duration of a focal or global neurological deficit <24 h, any variable neuroimaging does not demonstrate a new hemorrhage or infarct
No other readily identifiable nonstroke cause for the clinical presentation (eg, brain tumor, trauma, infection, hypoglycemia, peripheral lesion, pharmacological influences), to be determined by or in conjunction with the designated neurologist*
Confirmation of the diagnosis by at least 1 of the following:
Neurologist or neurosurgical specialist
Neuroimaging procedure (CT scan or brain MRI), but stroke may be diagnosed on clinical grounds alone
Stroke classification
Ischemic: an acute episode of focal cerebral, spinal, or retinal dysfunction caused by infarction of the central nervous system tissue
Hemorrhagic: an acute episode of focal or global cerebral or spinal dysfunction caused by intraparenchymal, intraventricular, or subarachnoid hemorrhage
A stroke may be classified as undetermined if there is insufficient information to allow categorization as ischemic or hemorrhagic
Stroke definitions†
Disabling stroke: an mRS score of 2 or more at 90 days and an increase in at least 1 mRS category from an individual's prestroke baseline
Nondisabling stroke: an mRS score of <2 at 90 days or one that does not result in an increase in at least 1 mRS category from an individual's prestroke baseline

mRS, Modified Rankin Scale. *Patients with nonfocal global encephalopathy will not be reported as a stroke without unequivocal evidence of cerebral infarction-based upon neuroimaging studies (CT scan or Brain MRI). †Modified Rankin Scale assessments should be made by qualified individuals according to a certification process.[23-25]

Supplementary Table 5 :

Myocardial infarction definitions according to VARC-2 consortium

TABLE 3. Myocardial infarction

Periprocedural MI (≤72 h after the index procedure)
- New ischemic symptoms (eg, chest pain or shortness of breath), or new ischemic signs (eg, ventricular arrhythmias, new or worsening heart failure, new ST-segment changes, hemodynamic instability, new pathological Q-waves in at least 2 contiguous leads, imaging evidence of new loss of viable myocardium or new wall motion abnormality) AND
- Elevated cardiac biomarkers (preferable CK-MB) within 72 h after the index procedure, consisting of at least 1 sample postprocedure with a peak value exceeding 15× as the upper reference limit for troponin or 5× for CK-MB.* If cardiac biomarkers are increased at baseline (>99th percentile), a further increase in at least 50% postprocedure is required AND the peak value must exceed the previously stated limit

Spontaneous MI (>72 h after the index procedure)
- Any 1 of the following criteria:
- Detection of rise and/or fall of cardiac biomarkers (preferably troponin) with at least 1 value above the 99th percentile URL, together with the evidence of myocardial ischemia with at least 1 of the following:
  - Symptoms of ischemia
  - ECG changes indicative of new ischemia [new ST-T changes or new left bundle branch block (LBBB)]
  - New pathological Q-waves in at least 2 contiguous leads
  - Imaging evidence of a new loss of viable myocardium or new wall motion abnormality
- Sudden, unexpected cardiac death, involving cardiac arrest, often with symptoms suggestive of myocardial ischemia, and accompanied by presumably new ST elevation, or new LBBB, and/or evidence of fresh thrombus by coronary angiography and/or at autopsy, but death occurring before blood samples could be obtained, or at a time before the appearance of cardiac biomarkers in the blood.
- Pathological findings of an acute myocardial infarction

*Previously in the original VARC it was 10× and 5× for troponin and CK-MB, respectively.

Supplementary Table 6 :

IMS Score

Table I: Iliac Morphology Score				
Variable	Absent = 0	Mild = 1	Moderate = 2	Severe = 3
Calcification	None	<25% vessel length	25-50% vessel length	>50% vessel length or any circumferential point
Minimum Diameter (mm)	>7.1	$6.4 < x \leq 7.1$	$5.5 < x \leq 6.4$	≤ 5.5

ILLUSTRATIONS :

Illustration 1 :

TAVI procedure final arteriography with femoral dissection.

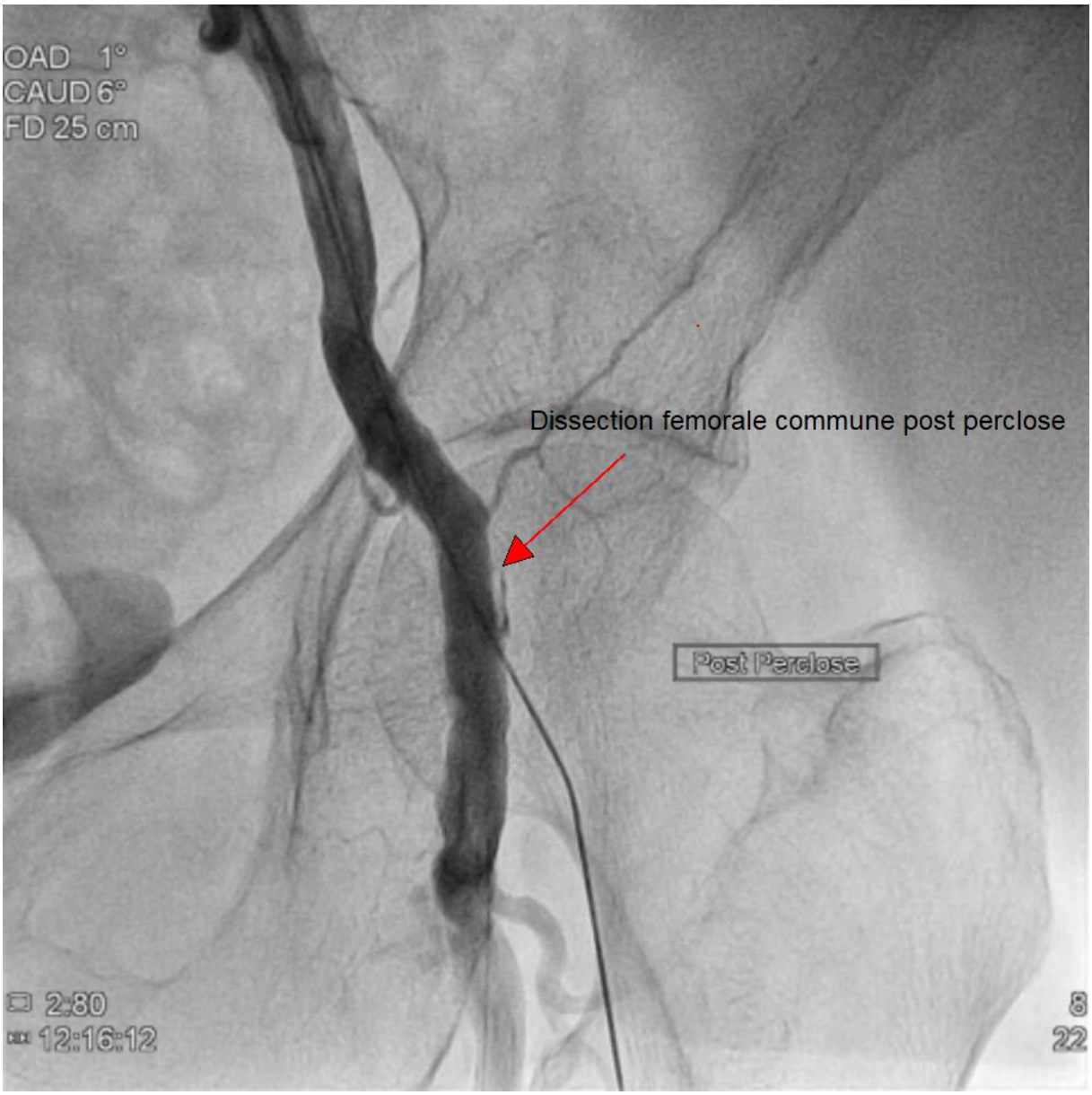


Illustration 2 :

Vascular complications – femoral occlusion after TAVI with Perclose Proglide® closure.

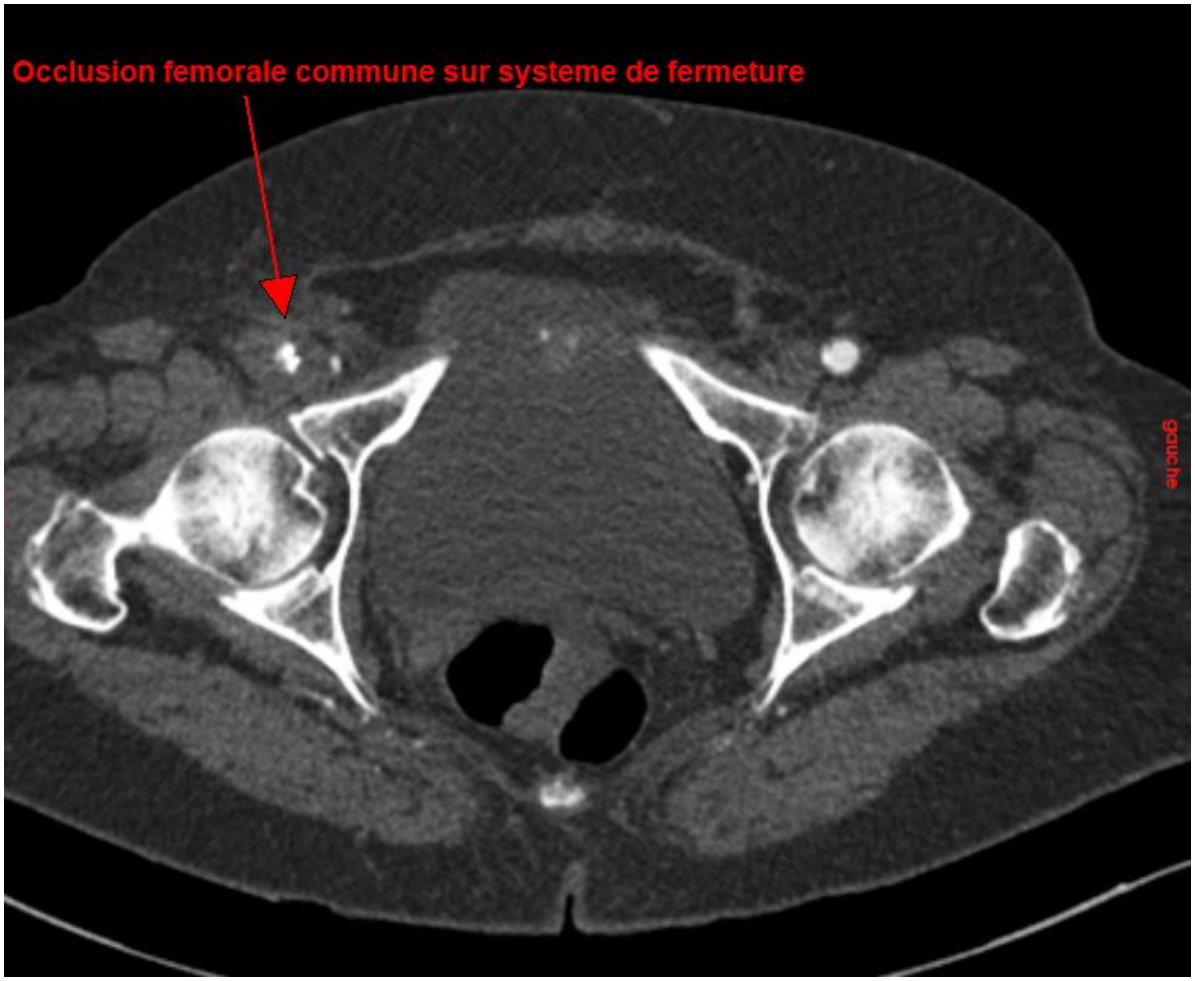


Illustration 3 :

Vascular complications – false aneurysm with femoral dissection after TAVI procedure.

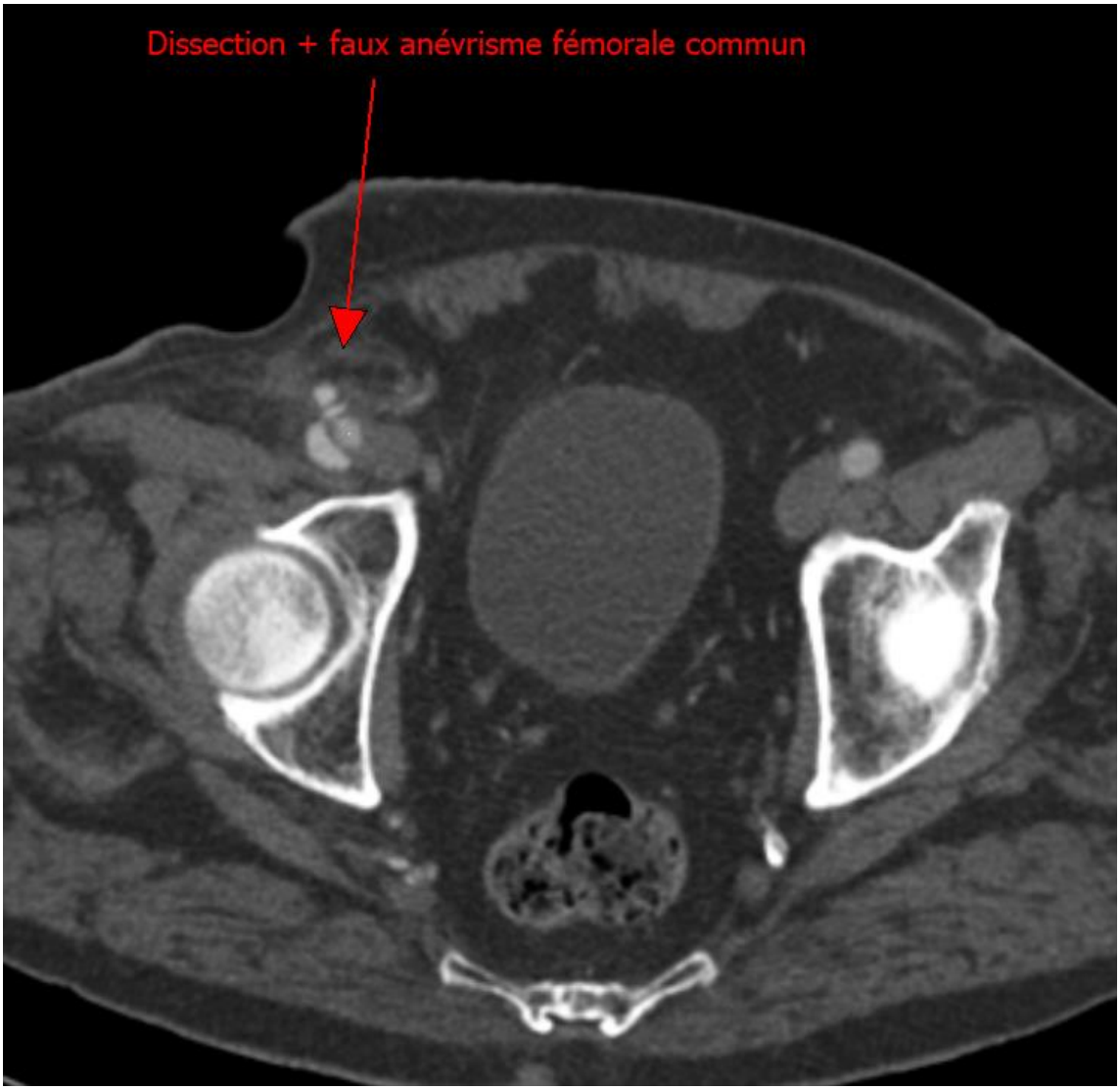


Illustration 4 :

Endovascular treatment of femoral false aneurysm and dissection with GORE® VIABAHN® endoprosthesis.

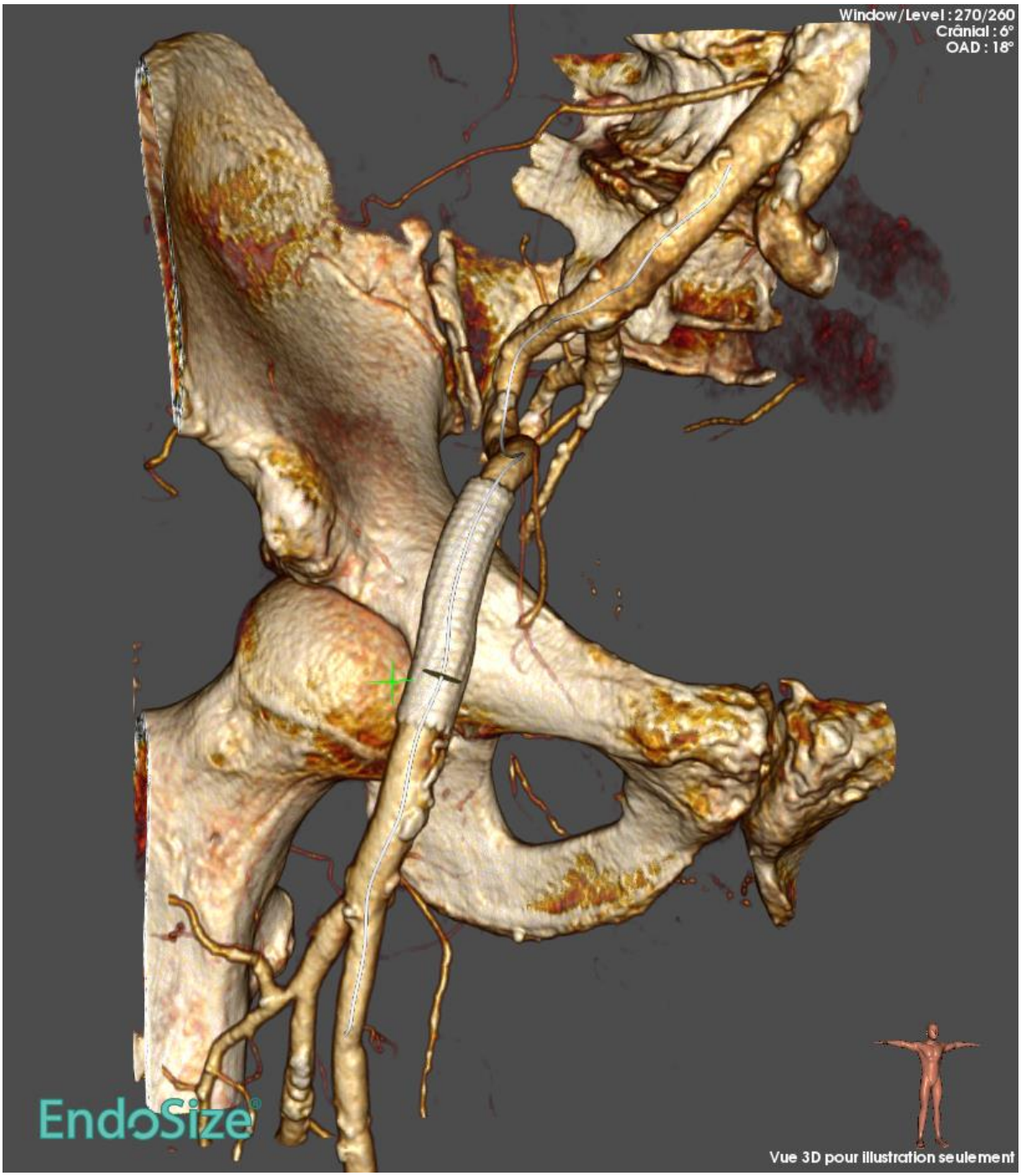


Illustration 5 :

Femoral false aneurysm with abdominal hematoma.

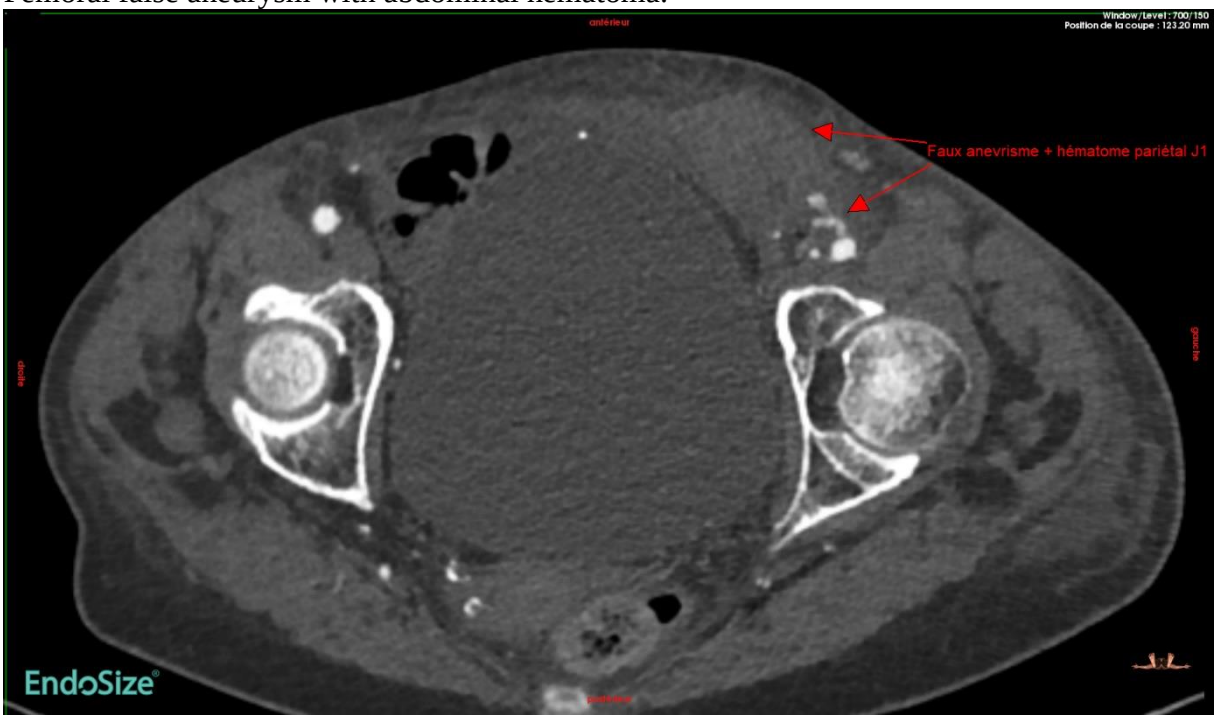
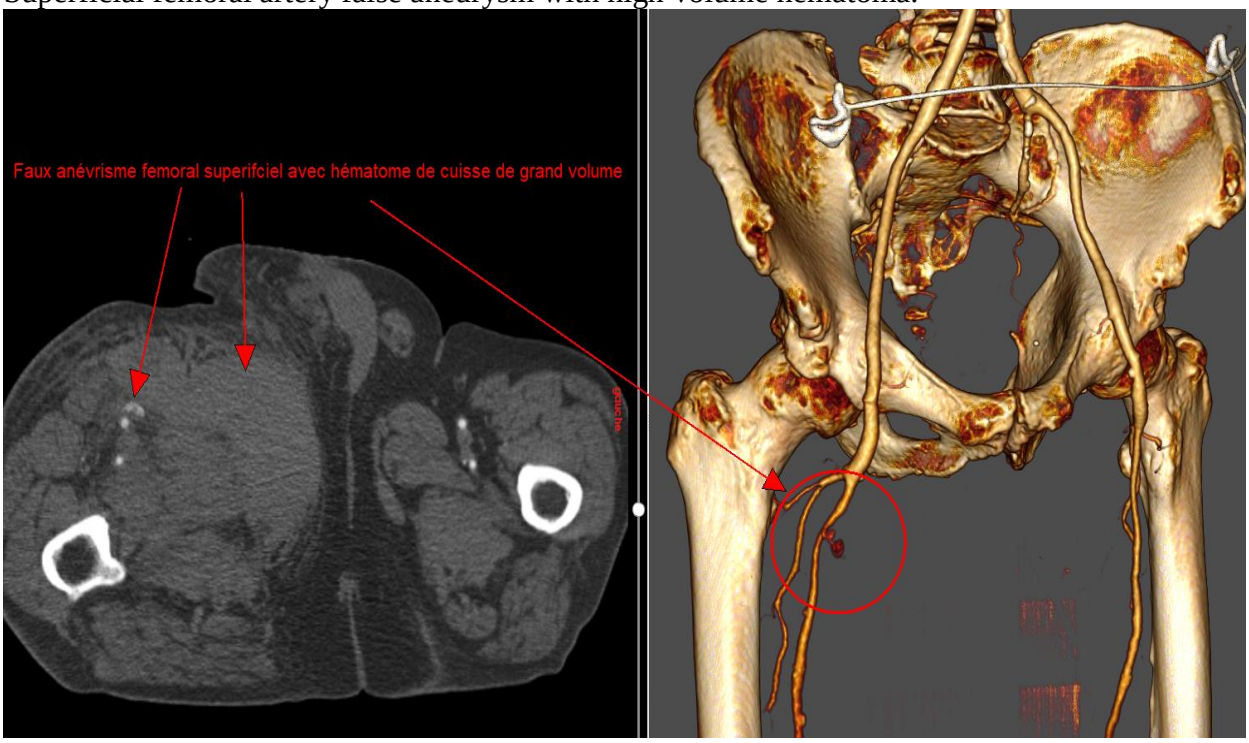


Illustration 6 :

Superficial femoral artery false aneurysm with high volume hematoma.



Vu, le Directeur de Thèse

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67 pages – 8 tableaux – 9 figures – 6 tableaux supplémentaires – 6 illustrations

Résumé :
Les complications vasculaires (CVs) des procédures TAVI sont associées à une augmentation de la morbi-mortalité intra-hospitalière. La littérature montre une incidence de ces complications de 20%, dont 14% sont mineures et 6% sont majeures. Nous avons inclus dans notre étude l'ensemble des patients ayant bénéficié d'une procédure TAVI en 2017 aux CHRU de Tours et de Rennes. Les complications vasculaires étaient recueillies selon les critères du Valve Academic Research Consortium (VARC-2). Les données cliniques et scanographiques étaient recueillies par un investigateur indépendant des procédures TAVI. Quatre cent soixante-dix-neuf patients ont été inclus prospectivement. L'incidence des CVs était de 25.9% (n=124 patients) dont 2.9% majeures (n=14) et 23% mineures (n=111). Les CVs étaient liées au point de ponction principal dans 69% des cas contre 31% au point de ponction secondaire. Les traitements mis en œuvre étaient médicaux (compressif) dans 76%, endovasculaires dans 9% et chirurgicaux dans 15% des CVs. Les facteurs de risques pour l'ensemble des CVs étaient : l'Iliac Morphology Score, le rapport des diamètres entre l'introducteur et le diamètre iliofémoral minimal (SIFAR), les calcifications iliofémorales modérées ou sévères et les tortuosités iliofémorales modérées ou sévères. Pour les CVs majeures, seul SIFAR était un facteur de risque. Les CVs étaient associées à une augmentation significative des saignements majeurs, aux accidents vasculaires cérébraux et aux durées d'hospitalisation. Les CVs majeures augmentaient significativement la mortalité intra-hospitalière et à 1 an contrairement aux CVs mineures.
La majorité des CVs sont mineures et fréquentes, les CVs majeures sont rares mais de pronostic sévère. Le point de ponction secondaire doit être surveillé activement. La détection précoce des CVs est nécessaire pour prévenir la transformation d'une complication mineure en majeure.

Mots clés : TAVI, complications vasculaires, VARC-2, SIFAR, calcifications iliofémorales, tortuosités iliofémorales.

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