Transapical Aortic Valve Implantation Without Angiography: Proof of Concept

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Background. **Cardiac computed tomographic scans, coronary angiograms, and aortographies are routinely performed in transcatheter heart valve therapies. Consequently, all patients are exposed to multiple contrast injections with a following risk of nephrotoxicity and postoperative renal failure. The transapical aortic valve implantation without angiography can prevent contrast-related complications.**

Methods. **Between November 2008 and November 2009, 30 consecutive high-risk patients (16 female, 53.3%) underwent transapical aortic valve implantation without angiography. The landmarks identification, the stent-valve positioning, and the postoperative control were routinely performed under transesophageal echocardiogram and fluoroscopic visualization without contrast injections.**

Results. **Mean age was 80.1 ± 8.7 years. Mean valve gradient, aortic orifice area, and ejection fraction were 60.3 ± 20.9 mm Hg, 0.7 ± 0.16 cm^2, and 0.526 ± 0.128, respectively. Risk factors were pulmonary hypertension (60%), peripheral vascular disease (70%), chronic pulmonary disease (50%), previous cardiac surgery (13.3%), and chronic renal insufficiency (40%) (mean blood creatinine and urea levels: 96.8 ± 54 μg/dL and 8.45 ± 5.15 mmol/L). Average European System for Cardiac Operative Risk Evaluation was 32.2 ± 13.3%. Valve deployment in the ideal landing zone was 96.7% successful and valve embolization occurred once. Thirty-day mortality was 10% (3 patients). Causes of death were the following: intraoperative ventricular rupture (conversion to sternotomy), right ventricular failure, and bilateral pneumonia. Stroke occurred in one patient at postoperative day 9. Renal failure (postoperative mean blood creatinine and urea levels: 91.1 ± 66.8 μg/dL and 7.27 ± 3.45 mmol/L), myocardial infarction, and atrioventricular block were not detected.**

Conclusions. **Transapical aortic valve implantation without angiography requires a short learning curve and can be performed routinely by experienced teams. Our report confirms that this procedure is feasible and safe, and provides good results with low incidence of postoperative renal disorders.**

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Transcatheter aortic valve implantation (TAVI) is a minimally invasive alternative to standard aortic valve replacement and, over the last 5 years, it has become an established procedure performed worldwide in highly qualified cardiac centers, with satisfactory short-term and midterm results. However, in the absence of long-term reports, TAVI remains addressed to patients with severe symptomatic aortic stenosis and at too high operative risk for standard open-heart surgery.

Traditionally, TAVI is performed through a transapical (TA), a transfemoral, or a trans-subclavian access (depending on concomitant vascular disease) and requires the identification of specific cardiac landmarks for the stent-valve positioning in the ideal landing zone. To visualize these landmarks, a good preoperative and intraoperative cardiac imaging is required and computed tomography (CT scan), coronary angiography, aortography, and transesophageal echocardiography (TEE) are routinely performed prior and during all transcatheter procedures [1–3]. Unfortunately, a consequence of this approach is that all patients are exposed to multiple contrast injections with a concrete risk of nephrotoxicity followed by acute postprocedural renal failure. Recent reports have confirmed that the incidence of renal disorders after TAVI can rise to 30% with, sometimes, transitory or permanent dialysis [4], and this phenomenon is amplified when concomitant comorbidities, such as peripheral vascular disease, chronic renal insufficiency (creatinine level above 110μmol/L), left ventricular dysfunction, diabetes or systemic hypertension, affect negatively the renal vascularization and function. In order to diminish the incidence of contrast-induced nephropathy (longer hospitalization and negative patient outcomes) we developed the concept of TA-TAVI without angiog-

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raphy built on our ten-year experience on endovascular aorta repair without contrast [5, 6].

Material and Methods

Between November 2008 and November 2009, 14 men and 16 females suffering from severe aortic valve stenosis underwent 30 consecutive TA-TAVI using 23 mm/26 mm Sapien stent-valves and Ascendra systems (Edwards Lifesciences, Irvine, CA).

All patients were extensively informed about the modified minimally invasive procedure and they all signed an informed consent following the guidelines of our internal ethical committee. All cases were performed under general anesthesia in the operating theater using high-quality C-arm fluoroscopy and TEE. To be ready for emergency cardiopulmonary bypass use, femoral vessels were routinely equipped with percutaneous guidewires and a long pigtail (110 cm) catheter was advanced into the ascending aorta against the aortic valve leaflets: the pigtail enabled for contrast injections (only in case of need) and represented a helpful fluoroscopic key-landmark during the stent-valve positioning.

To pre-configure the orientation of the C-arm fluoroscopy in the operating room all patients were placed in a standard supine position, without a slight elevation of the left chest, in order to recreate the same flat position encountered in the CT-scan machine (see the C-arm fluoroscopy preorientation session); with this expedient it was possible to compare the three-dimensional aortic root CT-scan reconstructions with the in vivo situation and consequently pre-orientate the fluoroscopy. To establish the technique, the first 8 patients received a very low dose of contrast medium (20 mL/patient) injected before the valve deployment to confirm the following: (1) the good pre-orientation of the C-arm fluoroscopy (100% of reliability for the fluoroscopy prepositioning); and (2) the correct position of the crimped Sapien valve already placed in the ideal landing zone using the TEE and the fluoroscopic visualization without contrast. The following 22 TA-TAVI cases were performed relying entirely on TEE plus concomitant fluoroscopy without angiography. As far as the surgical procedure is concerned, the left minithoracotomy (fifth intercostal space), the apex preparation (double reinforced 2-0 purse-string suture), the introduction of guidewires, pigtails and sheaths through the apex, the aortic valvuloplasty, and the stent-valve ballooning under rapid pacing were performed following the standard guidelines [1–3]. A procedural success was defined as successful deployment of at least one stent valve in the ideal landing zone with catheters retrieval, no conversion to conventional surgery, and patient exiting the operating room alive.

Patient Screening and Selection

The patients' recruitment followed the international guidelines for TA-TAVI [2]. The selection was performed on the basis of an increased operative risk profile calculated using the logistic European System for Cardiac Operative Risk Evaluation (EuroSCORE) system, and patients with a risk for hospital mortality above 20% were included in the protocol. Special cases with contraindications to cardiopulmonary bypass, sternotomy or aortic cross clamping, or patients collecting severe comorbidities not listed in the EuroSCORE (ie, liver cirrhosis) were also included. Moreover, we identified all concomitant disease contraindicating the intraoperative TEE use, such as liver cirrhosis with esophageal varices (Child classification; varices staging), previous esophageal surgery, or presence of esophageal diverticula. As a matter of fact, the procedure is based on TEE images and the presence of a formal contraindication to the TEE use can lead to one of these two options: (1) switch to standard TA-TAVI with contrast injections and absence of intraoperative TEE; (2) maintain a "no angiography" setting and replace the nonusable TEE with an intracardiac echocardiogram that requires a certain degree of experience and the presence of specific disposable Doppler probes.

Subsequently, a standard echocardiographic analysis and a CT-scan were performed to delineate the aortic annulus size, the pattern of cusp calcifications, and other relevant anatomic landmarks and measurements. If feasible, the therapeutic option of TA-TAVI without angiography was discussed with patients and informed consents were collected.

Preoperative Cardiac CT Scan

To measure the annulus diameter, the subaortic outflow tract diameter, the distance between the aortic annulus and the coronary ostia, and to identify coronary anomalies, valvular-structural calcifications, and anomalies, requires high-quality CT-scan images with three-dimensional reconstructions performed, preoperatively, by an experienced radiologist involved in the task force (Fig 1A) [7]. Moreover, TA-TAVI without angiography requires aortic root reconstructions to identify the orientation of the plane of the native aortic valve with respect to the 3 space dimensions and the patient's anatomy. Basically, a cranial and a left lateral position (in degrees) representing the orientation of the native aortic valve plane are preoperatively calculated by the radiologist and, subsequently, applied to the C-arm fluoroscopy in the operating room (Fig 2). To simplify the data interpretation by the team in the operating room, the aortic root reconstruction is superimposed onto a simple chest X-ray together with the cranial and the left lateral positions (Fig 1B). This useful and simple technique enables a precise fluoroscopy preinstallation in the theater (perfectly perpendicular to the plane of the native aortic valve, in order to avoid parallax phenomena between the 3 leaflets and the stent valve) and avoids multiple contrast injections and further C-arm adjustments.

C-Arm Fluoroscopy Preorientation

A TA-TAVI without angiography performed in the operating room requires a high quality C-arm fluoroscopy (at least 25 images/second). The machine is positioned to visualize the aortic root perpendicularly, and the three valve leaflets have to lie on one plane in order to avoid parallax phenomena during the stent-valve positioning and deployment. Traditionally, in standard TAVIs the orientation of the machine requires multiple contrast injections and several arm adjustments, whereas the TA-TAVI without angiography requires the preorientation of the C-arm using two positions (a cranial one and a left lateral one) precalculated using the three-dimensional aortic CT scan. In our experience, the first 8 injected patients confirmed in 100% of the cases a successful C-arm prepositioning (implying no need for further adjustments and contrast injections) and, after the deployments, the implanted stent valves lied perfectly perpendicular to the native aortic valve plane (an example is shown in Fig 1C). Moreover, during the key part of the procedure the fluoroscopy without angiography identifies valve calcifications, pigtail catheters, and guidewires (acting as landmarks), and controls the aortic valvuloplasty and the stent-valve positioning and deployment. In particular, the pigtail catheter inserted into the ascending aorta and advanced against the valve represents a primary landmark indicating (indirectly) the aortic wall "silhouette" and the aortic valve position, and its tip has to be placed at the center of the screen when the C-arm is blocked in its final position (see the schema in Fig 3).

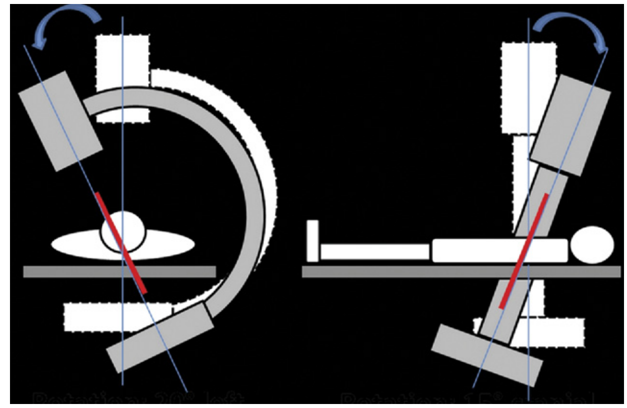

Fig 2. The schema represents the intraoperative positioning of the fluoroscopy, oriented laterally and cranially, after the computed tomographic scan measurements.

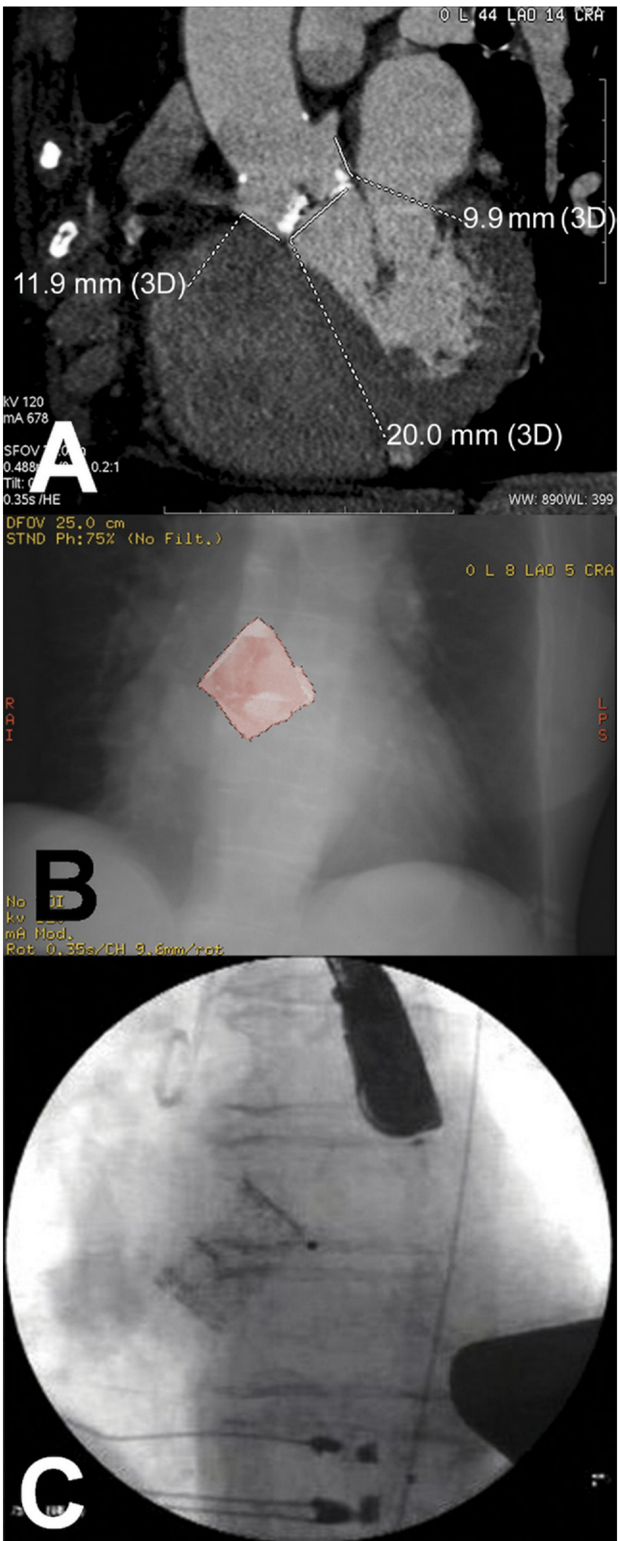

Fig 1. (A) The cardiac computed tomographic scan shows the aortic valve annulus diameter and the distance between the valve and the coronary ostia. (B) The aortic three-dimensional computed tomographic scan reconstruction is helpful for the C-arm fluoroscopy preorientation in the theatre (perpendicular to the aortic valve plane). In order to avoid contrast injections (required in standard TA-TAVIs for the positioning of the fluoroscopic machine), a left lateral and a cranial position (in degrees) are calculated preoperatively and, subsequently, applied to the C-arm. (C) The picture taken from the fluoroscopy shows a Sapien implanted in the ideal landing zone. After the preoperative computed tomographic scan measurements, the fluoroscopy was preorientated adequately with no need for further adjustments and contrast injections: the stent-valve appears perpendicular to the native aortic valve and confirms the good C-arm preorientation.

Transesophageal Echocardiogram

The TA-TAVI without angiography is based on two-dimensional TEE and a high-quality system is recom-

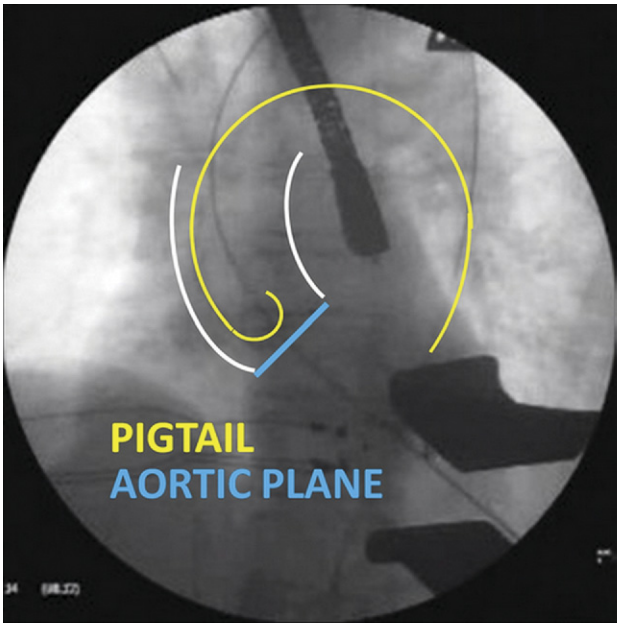

Fig 3. Schematic view from the fluoroscopy: the pigtail (yellow line) placed in the ascending aorta and advanced against the valve is a helpful landmark and should stay at the center of the screen. The valve calcifications visible (sometimes) under fluoroscopy also act as landmarks for the stent-valve positioning (blue line).

mended (the three-dimensional TEE is under evaluation). The first reported case of TA-TAVI without angiography and the first case of TA-TAVI fully guided by intracardiac echocardiography have already been reported from our team [8]. Adequate sharp ultrasound images should be guaranteed by expert cardiologists or anesthetists and any situation that can compromise the image quality (ie, shadows from a mechanical mitral prosthesis) must be intended as a contraindication. A TEE provides accurate aortic root measurements (long-axis), evaluates the amount and pattern of cusp calcifications (short-axis), and offers new precious anatomic markers such as the anterior leaflet of the mitral valve. The TEE allows the accurate positioning of the balloon for the valvuloplasty and allows for the accurate positioning of the crimped stent valve across the native calcified annulus: the metallic stent containing the valve is clearly visible under TEE and can be mixed-up very rarely with the balloon catheter (ie, in case of lack of coaxiality). In particular, the crimped stent valve should be placed across the native aortic ring (the hinge point of the aortic valve leaflets are the key landmarks for the positioning) with 1/3 of the stent in the aortic side and 2/3 in the ventricular side (schema in Fig 4). During the valvuloplasty and the deployment, TEE and fluoroscopic images are taken simultaneously with no need for contrast injections (Fig 5). After the procedure, TEE provides information about coronary patency, stent-valve motion and position, transvalvular gradients, and presence of paravalvular leaks.

Statement of Responsibility

Principal investigators had full access to the reported data and take responsibility for their integrity. All authors have read and agreed to the manuscript as written.

Results

Preoperative patient characteristics are listed in Table 1. Thirty consecutive patients suffering from aortic stenosis underwent TA-TAVI in our center: the mean age and the calculated logistic EuroSCORE were 80.1 ± 8.7 years and 32.2 ± 13.3%, respectively. Additional comorbidities, not included in the EuroSCORE, were severe liver cirrhosis (2 patients), calcified ascending aorta (2 patients), and previous radiotherapy for mediastinal and breast cancer (2 patients). All patients underwent a preoperative assessment with an echocardiogram and a CT scan (details in Table 2). With regard to the C-arm fluoroscopy preorientation, the mean left lateral and cranial position were 17.4 ± 6.3 degrees and 9.8 ± 5.15 degrees, respectively, and the machine prepositioning was 100% successful, according to the intraoperative angiographic control (first 8 cases) and the postimplantation fluoroscopic control, with no need for further C-arm adjustments and contrast injections.

The stent-valve implantation was successful in 29 cases (96.7%) and one patient (patient no.7) experienced a valve embolization caused by blood ejections during the (not efficient) rapid pacing: once the first Sapien migrated distally in the aortic arch, a second one was rapidly prepared and successfully implanted in the ideal landing zone. Because of the excellent patient's hemodynamic parameters, we decided not to explant the embolized stent-valve and the postoperative recovery was uneventful with fast-track extubation.

The overall 30-day mortality was 10%. In one case (patient no.16) the Sapien implantation in the ideal landing zone was followed, a few minutes later, by a

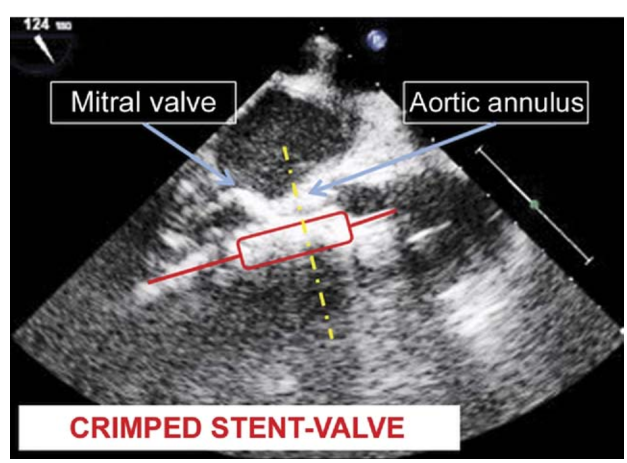

Fig 4. Transesophageal echocardiogram allows for the positioning of the crimped valve across the native aortic annulus. (Key: landmarks are the hinge point of the aortic leaflets, the calcifications, the anterior mitral valve leaflet, and the Valsalva sinuses).

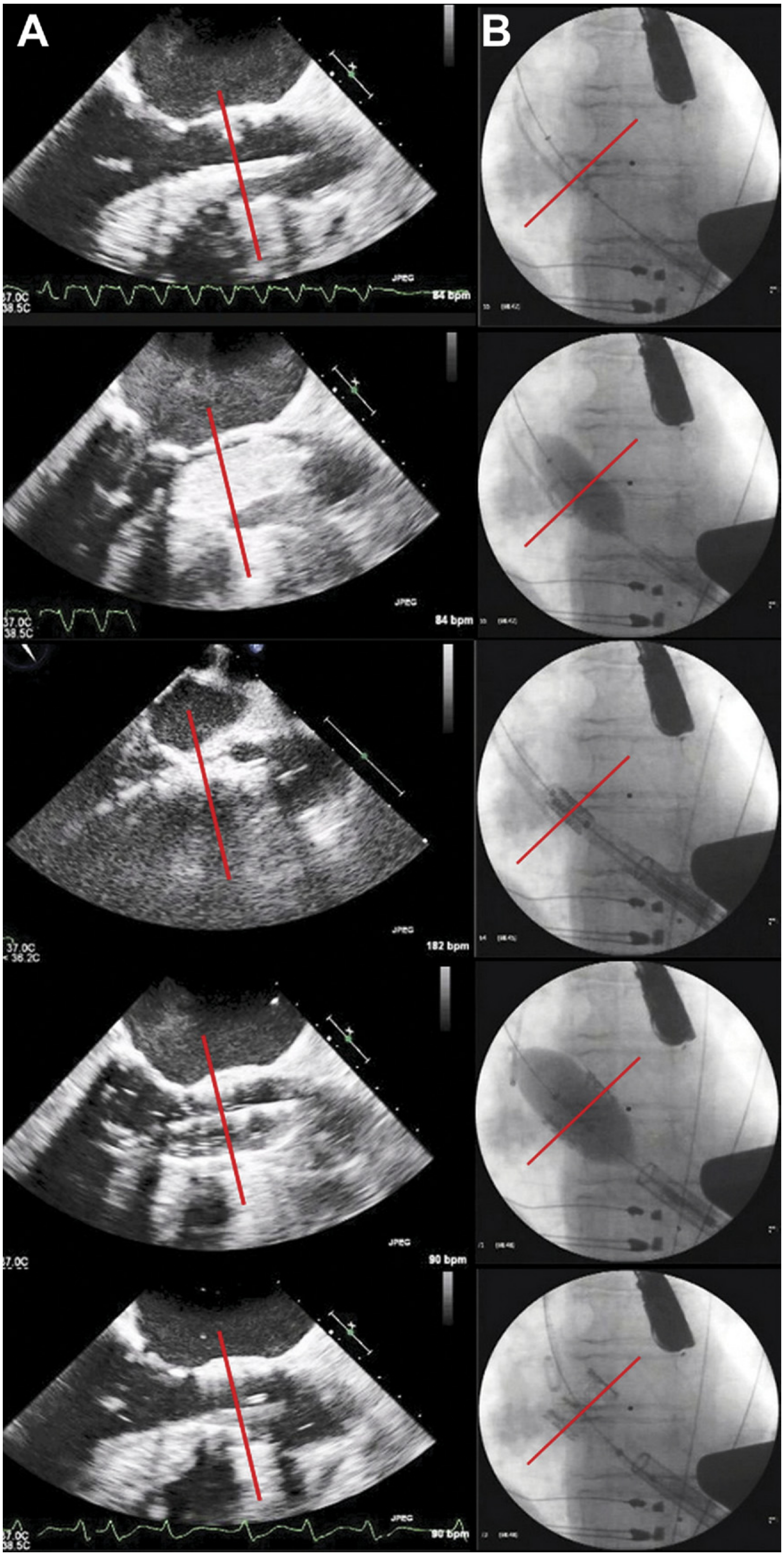

Fig 5. A transapical-transcatheter aortic valve implantation without angiography. (A) Images from the transesophageal echocardiogram showing the key phases of the procedure; the valve ballooning, the stent-valve positioning and the deployment. (B) The same key phases for the Sapien implantation are controlled by a preconfigured fluoroscopy. The red line represents the plane of the native aortic valve.

Table 1. Preoperative Characteristics

Patients	30
Age (years)	80.1 ± 8.7 (range 59–95)
Female	15 (57.7%)
Body weight (kg)	68 ± 15
Mean logistic EuroSCORE (%)	32.2 ± 13.3 (range 18–60)
Previous cardiac surgery	4 (13.3%)
Coronary surgery: 3	
Aortic arch surgery: 1	
Previous coronary angioplasty ± stenting	2 (6.6%)
Coronary disease	11 (36.7%)
Recent myocardial infarction	3 (10%)
Previous stroke	4 (13.3%)
Peripheral vascular disease	21 (70%)
Porcelain aorta	2 (6.6%)
Previous vascular surgery	6 (20%)
Chronic pulmonary disease	15 (50%)
Dialysis	1 (3.3%)
Chronic renal insufficiency	12 (40%)
Mean blood creatinine level: 96.8 ± 54 μg/dL	(range 53–339 μg/dL)
Mean blood urea level: 8.45 ± 5.15 mmol/L	(range 3.5–29.4 mmol/L)
Hypertension	17 (56.6%)
Diabetes	5 (16.6%)
Severe liver disease (cirrhosis)	2 (6.6%)
CHILD A: 1 patient	
CHILD B: 1 patient	
Grade II esophageal varices: 1 pt (CHILD 2 patient)	
Previous thoracic radiotherapy	2 (6.6%)

Data are presented as mean ± SD or N (%).

CHILD = classification for liver dysfunction; EuroSCORE = European System for Cardiac Operative Risk Evaluation; pt = patient.

life-threatening left ventricular free wall rupture (the region between the anterior descending and the circumflex coronary artery, below the pulmonary artery, far away from the apex) that required a prompt conversion to sternotomy and on-pump resuscitation. Unfortunately, after the repair of the large tear, all attempts to stop the heart-lung machine were unsuccessful and the patient died in theater. The tear was probably due to the presence of a small aortic annulus (20 mm) with very fragile cardiac tissues and a subaortic septal spur reducing the diameter of the left ventricle outflow tract. In another case (patient no. 25), an old woman carrying severe comorbidities and a right ventricular dysfunction due to a recent (1.5 months) right myocardial infarction plus pulmonary embolisms (compassionate case, EuroSCORE 60%), required the positioning of a femoro-femoral extracorporeal machine oxygenator at postoperative day 1; seven days later, the weaning of the machine was followed by severe multiorgan failure and death. The third patient, a 95-year-old woman, died during the postoperative recovery, at day 25, for severe bilateral pneumonia. All postoperative results are summarized in Table 3.

Interestingly, in our short series we never experienced bleeding from the punctured apex, postoperative renal failure (following the risk, injury, failure, loss, and end-stage kidney disease classification [9], with a mean postoperative blood creatinine level of 91.1 ± 66.8 μmol/L), transitory dialysis, myocardial infarction, intraaortic balloon pump use, and atrioventricular block. Unfortunately, despite an efficient anticoagulation therapy (aspirin plus warfarin) a 94-year-old woman with an otherwise uncomplicated postoperative recovery, experienced a sudden left hemiplegia at postoperative day 9, followed by a slow and incomplete regression of symptoms. The cerebral CT scan showed signs of ischemic attack and an embolic origin was assumed. Postoperative hemodynamic results are listed in Table 4.

Comment

We recently introduced the TA-TAVI without angiography in our routine practice in order to prevent postoperative renal failure in high-risk patients requiring minimally invasive aortic valve surgery. In fact, it is well known that the extensive use of contrast medium in the elderly with multiple concomitant comorbidities can induce nephrotoxicity with subsequent renal insufficiency and (sometimes) need for transitory dialysis: such a scenario can cause prolonged hospital recoveries and negative patients' outcomes with a higher incidence of morbidity and mortality [10–18]. Unfortunately, the preoperative imaging with contrast (CT scans and coronary angiograms) cannot be avoided in the clinical practice, but we have tried to reduce as much as possible the quantity of contrast medium employed during all CT scans performed for patients requiring TAVI: specifically (1) the injected dose, in mL, never overtook the patient's body weight; (2) all patients with preoperative chronic renal insufficiency (one patient was in predialysis with a creatinine level of 339 μg/dL) were fully prepared before the scan, following standard protocols; and (3) in order to

Table 2. Hemodynamic and Anatomic Details (n = 30)

Mean ejection fraction	0.526 ± 0.128
Mean aortic orifice area (cm^2)	0.7 ± 0.16
Mean aortic gradient (mm Hg)	60.3 ± 20.9
Pulmonary hypertension	18 (60%)
Left ventricle hypertrophy	
Mild	7 (23.3%)
Severe	3 (10%)
Mean aortic annulus diameter (mm)[a]	23 ± 1.7
Mean distance between the annulus and the LCA (mm)	11.1 ± 1.9
Mean distance between the annulus and the RCA (mm)	11.5 ± 1.9

[a] The annulus diameters were calculated by computed tomographic scan and transthoracic echocardiogram. The measurements were confirmed intraoperatively by transesophageal echocardiogram.

Data are presented as mean ± SD or N (%).

LCA = left coronary artery; RCA = right coronary artery.

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recover the impaired renal function we always waited at least 10 days (in case of clinical stability) before proceeding to the TA-TAVI procedure.

As far as the intraoperative strategies are concerned, we already reported [8] that implanting stent-valves using TEE and fluoroscopy guidance without contrast injections is feasible and safe. In the present study, we have analyzed our first series of 30 consecutive TA-TAVI cases performed without angiography and short-term results are satisfactory and encouraging, with a 30-day mortality rate (10%) and a postoperative complication rate in line with the most recent TA-TAVI results appearing in literature [4, 18–20]. In particular, our patients never experienced postoperative renal failure, myocardial infarction, or atrioventricular block requiring pacemaker implantation. In their large series of 50 consecutive standard TA-TAVI, Walther and colleagues [18] described similar results with the exception of a higher incidence of post-procedural renal disorders: the 30-day mortality was 8%, three patients required early conversion to sternotomy (6%), 2 patients were in permanent atrioventricular block (pacemaker), and 7 patients (14%) required a postoperative temporary renal replacement therapy for contrast media-induced nephropathy (preoperative chronic renal insufficiency, 14%; mean injected contrast, 82 ± 31 mL, range 15 to 150 mL). Another series of 26 consecutive standard TA-TAVI from Zierer and colleagues [19] showed a 30-day mortality of 15% with 2 conversions to sternotomy and 3 patients (12%) requiring postoperative transient hemofiltration (preoperative chronic renal insufficiency, 38%; no data about the injected doses of contrast medium). A third paper from the group of John Webb (Ye and colleagues [20]) also reported 26 consecutive standard TA-TAVI with interesting results: 23% of in-hospital mortality; 12% of atrioventricular block requiring pacemaker implantations; no conversions to sternotomy; and total absence of postoperative renal failure despite the cohort of patients presented a 46% of preoperative chronic renal insufficiency. Unfortunately, data about the injected doses of employed contrast medium are not available.

In conclusion, routine TA-TAVI without angiography is feasible, safe, and provides satisfactory hospital results comparable with the standard TA-TAVI technique, with a lower incidence of postoperative renal failure.

Table 3. Operative Results (n = 30)

Sapien stent valves employed	31 (11 × 23 mm; 20 × 26 mm)
Mean diameter (mm)	25 ± 1.44
Successful procedures	29 (96.7%)
Valve embolization	1 (3.3%)
Mean operating time (minutes)	116.4 ± 31.4
Mean contrast given (mL) (first 8 patients)	5.5 ± 9.1 (range 0–20)
Procedures performed without contrast	22 cases (73.3%)
Intraaortic balloon pump	0
Conversion to sternotomy	1 (3.3%)
Emergency cardiopulmonary bypass	1 (3.3%)
Early extubation (same day extubation)	24 (80%)
Extubation in theater	7 (23.3%)
Long intubation in intensive care unit	1 (3.3%)
30-day mortality	3 (10%)
Causes of death:	
Right cardiac failure	1 (3.3%)
Intraoperative left ventricular rupture	1 (3.3%)
Bilateral pneumonia	1 (3.3%)
Postoperative renal failure	0
Mean blood creatinine level: 91.1 ± 66.8 μg/dL	
Mean blood urea: 7.27 ± 3.45 mmol/L	
Postoperative myocardial infarction	0
Exploration for bleeding (nonapical)	2 (6.6%)
Right cardiac failure	1 (3.3%)
Postoperative ECMO	1 (3.3%)
Stroke (postoperative day 9)	1 (3.3%)
Pneumonia	2 (6.6%)
Postoperative atrioventricular block	0
Mean intensive care unit stay (days)	2.4 ± 4 (median:1) (range 1–20)
Mean hospital stay (days)	15.1 ± 10.2 (median:12)

Data are presented as mean ± SD, median or N (%).

ECMO = extracorporeal machine oxygenator intraaortic balloon pump.

Table 4. Echocardiographic Results

Peak aortic valve gradient (mm Hg)	14.1 ± 8.8
Mean aortic valve gradient (mm Hg)	7.7 ± 4.8
Mean ejection fraction	0.557 ± 0.105
Paravalvular leak:	
Any	24 (80%)
Minimal (1°)	3 (10%)
Moderate (2°)	3 (10%)

Data are presented as mean ± SD or N (%).

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INVITED COMMENTARY

Transcatheter aortic valve implantation (AVI) has been established into clinical practice using a retrograde transfemoral or an antegrade transapical approach. Thousands of elderly high-risk patients have been treated worldwide thus far, especially in Europe where CE approval was granted 2 years prior to the writing of this article. Optimal imaging is an indispensable prerequisite for these procedures so that transcatheter valves can be safely positioned inside the aortic annulus while still allowing for unimpeded coronary blood flow. During the past few years, conventional fluoroscopy and angiography have been most widely used for transfemoral and transapical AVI, however, imminent drawbacks, such as the need for contrast use has become apparent, especially in patients with impaired renal function as well as potential radiation. Under these circumstances the use of transesophageal echocardiography is a logical step.

Ferrari and colleagues [1] are presenting their results on echocardiographic imaging in this issue of *The Annals of Thoracic Surgery*. First, the team from Lausanne has to be congratulated for their interest and research in this field. They were able to transapically implant 29 of 30 patients with one valve embolization, using fluoroscopy in all but angiography, and thus contrast dye injections in the initial 8 patients only. Renal failure did not postoperatively occur in any patient. These results on "contrast free" transapical AVI seem promising. However, some important aspects have to be mentioned as follows: Visualization of the crimped valve in relation to the balloon under transesophageal echocardiography should be improved, possibly by means of specific markers at the upper and lower edges of the stent. Online three-dimensional transesophageal echocardiography may lead to further improved visualization of the specific targets. However, we will have to keep in mind that there are patients with excellent echocardiographic windows and others in whom precise visualization can not be fully accomplished.

In addition, further developments in three-dimensional computed tomographic (CT) techniques will certainly lead to improved imaging during transcatheter AVI in the future. Ferrari and colleagues [1] are describing their technique of orienting the C-arm during fluoroscopy, according to the preoperatively determined angulation as measured by CT, in parallel to positioning the patient in a similarly supine position as during acquisition of the preoperative CT images. This has obviously worked well in their 30 patients, and they had tested their approach by control angiography in the initial 8 patients. However, we have to keep in mind that there is some contrast requirement (average, 100 cc) for the preoperative CT scan, and that at present no perfect registration of the preoperative images exists. Some variation in patient positioning, patterns of perioperative ventilation, or even cardiac manipulation during the procedure may eventually lead to a nonperfect superimposition. Complete registration of the preoperative CT will certainly be feasible in due course.

In parallel, the development of intraoperative-advanced imaging techniques, such as DynaCT [2] might avoid preoperative CT and thereby a significant amount of contrast dye in the near future. After the evolution and evaluation of a triggered, thus absolutely accurate online overlay mode, this technique would offer another option for precise transcatheter valve positioning and implantation with minimal contrast requirements (20 cc) only.

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