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A New Transcatheter Aortic Valve and Percutaneous Valve Delivery System

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Objectives We describe procedural and clinical outcomes in a high-risk cohort undergoing transcatheter aortic valve replacement with early next-generation transcatheter valve and delivery systems.

Background Percutaneous aortic valve replacement is gaining acceptance as a viable option in patients at high surgical risk. Broader application will require further advances in valve and delivery system technology.

Methods Transarterial aortic valve replacement was attempted in 25 patients (mean age 85 years) determined to be at high surgical risk due to comorbidities. A new delivery catheter system (RetroFlex 2, Edwards Lifesciences, Irving, California) was utilized in combination with either a balloon-expandable SAPIEN (Edwards Lifesciences) valve or a next-generation low-profile cobalt-chromium bovine pericardial SAPIEN XT (Edwards Lifesciences) valve.

Results Percutaneous valve replacement was successful in all 25 high-risk patients. Aortic valve area increased from 0.59 ± 0.15 cm^2 to 1.60 ± 0.27 cm^2. In this high-risk cohort (Society of Thoracic Surgeons and logistic EuroSCORE estimates of surgical mortality were 8.9% and 21.0%, respectively), 30-day mortality was 0%.

Conclusions Technical and procedural advances in catheter systems and prosthetic valves designed for percutaneous aortic valve delivery may contribute to increased procedural success and improved clinical outcomes. (J Am Coll Cardiol 2009;53:1855–8) © 2009 by the American College of Cardiology Foundation

Initial attempts at percutaneous aortic valve replacement (AVR) were compromised due to the difficulties associated with vascular passage of a relatively bulky prosthetic valve compressed onto a standard valvuloplasty catheter (1,2). Subsequent technical and procedural improvements allowed the development of a more predictable therapy (3). Although outcomes continue to improve, limitations (aortic injury, atheroembolism, difficulty crossing the native valve) remain apparent (4). We describe a new delivery system and next-generation balloon-expandable valve in a case series of 25 high-risk patients undergoing transarterial AVR.

Methods

Percutaneous AVR was approved for clinical use in patients with symptomatic aortic stenosis in whom the risk associated with open heart surgery was considered prohibitive by a team of cardiologists and cardiac surgeons. Written informed consent was obtained. Patients were excluded if the diameter of the aortic annulus was <18 or >26 mm as assessed by transesophageal echocardiography, if there was severe iliofemoral arterial disease, or if a reasonable quality or duration of life was considered unlikely.

Procedures were performed in a catheterization laboratory under general anesthesia. Percutaneous femoral artery puncture was utilized followed by percutaneous suture "pre-closure" (Prostar, Abbott, Boston, Massachusetts) or surgical cutdown. The basic procedure of transarterial AVR has been previously described (3,4).

Delivery system. The RetroFlex 2 delivery system (Edwards Lifesciences, Irvine, California) incorporates a coaxial nose cone catheter, a balloon catheter, and a deflectable pusher catheter (Fig. 1). The catheter is advanced through the sheath and into the aorta. An articulation control knob allows steering around the aortic arch and through the central orifice of the stenotic native valve. The deflectable pusher catheter is retracted, and the nose cone is advanced so as to expose the deployment balloon (Fig. 2). The prosthesis is positioned within the native valve. The deployment balloon is inflated and deflated while right ventricular burst pacing is used to temporarily reduce transvalvular flow. The balloon is utilized to guide the withdrawal of the nose cone through the newly implanted valve. The nose cone and pusher catheter are approximated and removed through the delivery sheath.

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Abbreviations and Acronyms

AVR = aortic valve replacement

IQR = interquartile range

Valves. Initial reports of balloon-expandable valve replacement utilized a valve constructed from a stainless steel tubular frame with equine pericardial leaflets and a fabric sealing cuff (Cribier-Edwards, Edwards Lifesciences). This basic valve design was subsequently modified utilizing bovine pericardial leaflets and lengthening the sealing cuff without modification of the frame (SAPIEN, Edwards Lifesciences).

A next-generation transcatheter heart valve (SAPIEN XT, Edwards Lifesciences) was utilized in 3 patients. A cobalt-chromium frame permits thinner struts without loss of structural integrity. Thinner struts and a more open design allow for a lower crimped profile (Fig. 3), while maintaining the valve's radial stiffness. Bovine pericardial leaflets are matched for thickness and elasticity and incorporate Thermafix anticalcification treatment. The scalloped geometry and attachment method of the leaflets have been modified to achieve a naturally closed design and enhance valve durability (Fig. 4).

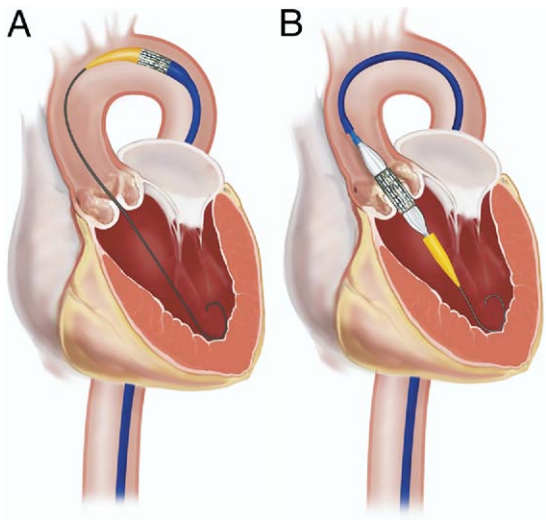

Figure 1 **Diagrammatic Representation Showing the RetroFlex 2 Catheter System**

The catheter system is shown during passage through the aorta **(left)** and with the nosecone advanced and flexion catheter withdrawn to allow expansion of the deployment balloon **(right)**.

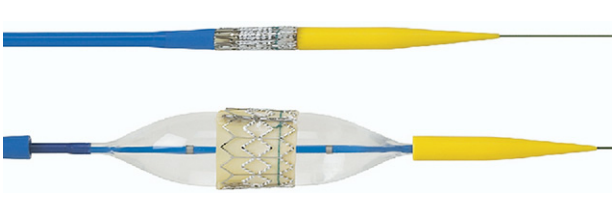

Figure 2 **Photograph of RetroFlex 2 Catheter**

The catheter is shown during introduction **(top)** and with the balloon exposed to allow deployment of the prosthesis **(bottom)**.

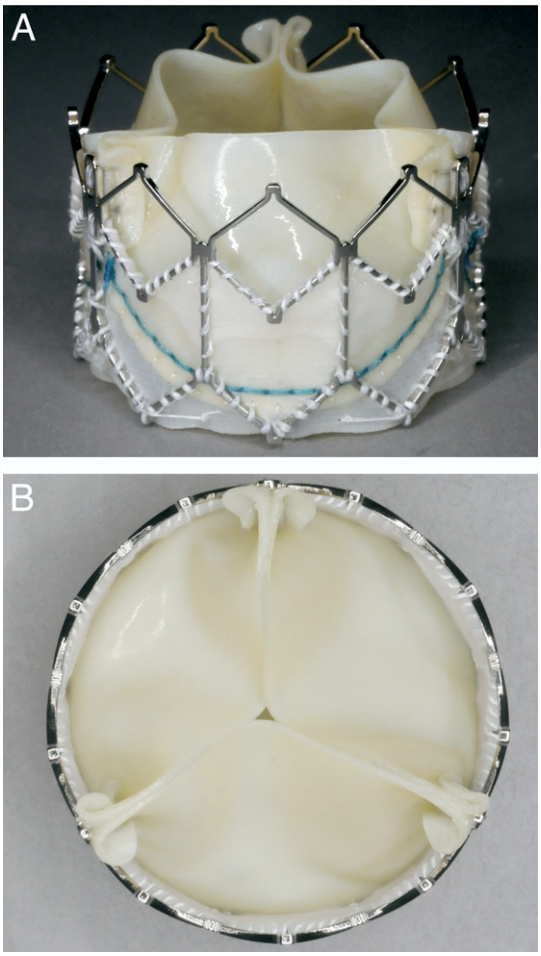

Figure 3 **Low-Profile Next-Generation SAPIEN XT Valve**

The thin cobalt-chromium struts and relatively open frame allow a low delivery profile without loss of radial strength **(A)**. Unlike the SAPIEN valve, the scalloped leaflets are closed at rest. The scalloped geometry of the bovine pericardial leaflets results in superior durability as assessed by in vitro testing **(B)**.

The femoral arterial sheath required is determined by the crimped diameter of the prosthetic valve and its delivery system. A 23-mm SAPIEN valve crimped on the RetroFlex 2 delivery catheter requires a 22-F internal diameter sheath, whereas a 26-mm SAPIEN valve requires a 24-F sheath. When crimped on the current RetroFlex 2 catheter, the 26-mm next-generation low-profile valve allows use of a 22-F sheath.

Statistics. Continuous variables are presented as mean ± SD, medians, and interquartile ranges (IQRs), as appropriate. Categorical variables are stated as frequencies and percentages. Normality was tested with the Kolmogorov-Smirnov goodness-of-fit test. For comparison of continuous variables before and after transarterial AVR, the Student *t*

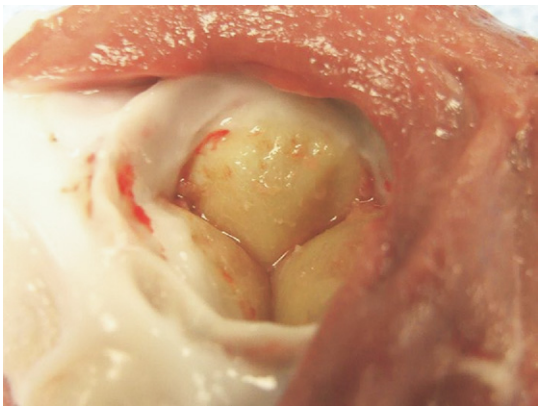

Figure 4 Low-Profile Next-Generation Cobalt-Chromium SAPIEN XT Valve Explanted at 20 Weeks From a Sheep

Tissue growth over the inflow portion of the frame can be seen.

test was used, and for comparison of groups, a 1-way analysis of variance F test was utilized. Categorical variables were compared by the Fisher exact test. A 2-sided value of $p < 0.05$ was considered statistically significant.

Results

The RetroFlex 2 system was utilized in 25 patients. Mean age was 85 years (IQR: 79 to 88 years). Patients had multiple comorbidities, including prior thoracotomy (28%), renal insufficiency (40%), porcelain aorta (12%), grade 3 or 4 mitral regurgitation (12%), severe lung disease (24%), and severe frailty (40%). Baseline characteristics are presented in Table 1.

Table 1 Baseline Characteristics of 25 High-Risk Patients

Characteristic	
Age, yrs	85 (79–88)
Female sex	13 (52)
New York Heart Association functional class	
I	1 (4)
II	2 (8)
III	14 (56)
IV	8 (32)
Diabetes	6 (24)
Coronary artery disease	12 (48)
Severe lung disease	6 (24)
Prior cerebral ischemic event	2 (8)
Peripheral vascular disease	3 (12)
Prior thoracotomy	7 (28)
Prior coronary bypass surgery	6 (24)
Prior angioplasty	10 (40)
Estimated glomerular filtration rate <60 ml/min	10 (40)
Ejection fraction <50%	4 (16)
Mitral regurgitation (moderate or severe)	3 (12)
Pulmonary hypertension >60 mm Hg	6 (24)
Porcelain aorta	3 (12)
Frail and poor mobility	10 (40)
Logistic EuroSCORE (5)	21 (15–30)
STS	8.9 (6.0–12.4)

Values are n (%) or median (interquartile range).
STS = Society of Thoracic Surgery National Database risk calculator estimated 30-day surgical mortality.

Table 2 Outcome at 30 Days

Characteristic	n (%)
Procedural success	25 (100)
Nondisabling stroke	2 (8)
Disabling stroke	0 (0)
Myocardial infarction	0 (0)
Ventricular fibrillation	0 (0)
Heart block, new and sustained	0 (0)
Tamponade	0 (0)
Transfusion ≥3 U	3 (12)
Percutaneous access	25 (100)
Percutaneous closure	16 (64)
Emergent cardiac surgery	0 (0)
Intra-aortic counterpulsation	1 (1)
Femoral–femoral support	1 (4)
Endocarditis	0 (0)
New requirement for dialysis	0 (0)
Death, intraprocedural	0 (0)
Death, 30 days	0 (0)
Death, stroke, or myocardial infarction at 30 days	2 (8)
Death, disabling stroke, myocardial infarction at 30 days	0 (0)

Procedural success, defined as implantation of a prosthesis at the intended site, was achieved in all patients. Tortuosity of the thoracic aorta, horizontal aortic roots, and severely stenotic, heavily calcified valves, although problematic with earlier delivery systems, were relatively easily managed with the new delivery system. Percutaneous needle puncture was utilized for femoral arterial access in all patients and percutaneous suture closure in the majority. Outcomes are presented in Table 2. Society of Thoracic Surgeons and logistic EuroSCORE estimates of operative 30-day mortality were 8.9% and 21.0%, respectively. All patients remained alive at 30 days.

The SAPIEN valve was utilized in 22 patients and the next generation low profile cobalt-chromium SAPIEN XT valve in 3. At discharge, echocardiographic aortic mean gradient had fallen from 49.3 ± 17.9 mm Hg to 10.6 ± 2.9 mm Hg and effective orifice area had risen from 0.59 ± 0.15 cm^2 to 1.6 ± 0.27 cm^2 (Table 3). No patient had more than mild valvular regurgitation, and only 1 patient had more than mild paravalvular regurgitation (graded moderate). All patients had normal prosthetic valve function at 1-month echocardiographic follow-up.

Discussion

Transcatheter valve replacement continues to evolve rapidly. In the initial experience with transarterial AVR, procedural success was achieved in 78% of patients with a 30-day

Table 3 Echocardiographic Valve Function

	All Patients (n = 25)		SAPIEN Valve (n = 22)		Next Generation Valve (n = 3)	
	Baseline	Discharge	Baseline	Discharge	Baseline	Discharge
Mean gradient (mm Hg)	49.3 ± 17.9	10.6 ± 2.9*	49.0 ± 17.9	10.7 ± 3.0*	51.3 ± 17.6	10.0 ± 1.4†
Effective orifice area (cm^2)	0.59 ± 0.15	1.6 ± 0.27*	0.58 ± 0.14	1.6 ± 0.28*	0.63 ± 0.21	1.7 ± 0.07
Valvular regurgitation > mild	0	0	0	0	0	0
Paravalvular regurgitation > mild	—	0	—	1	—	0

*$p < 0.0001$ versus baseline; †$p < 0.05$ versus baseline, no differences among groups were observed.

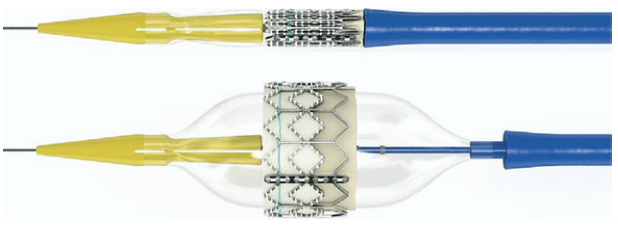

Figure 5 Photograph of RetroFlex 3 Catheter

More recently the RetroFlex 3 catheter has seen early clinical use. This system incorporates a shorter fixed nose cone for ease of use and safety. Future modifications in RetroFlex 4 will reduce profile further.

mortality of 11% (3). The current success rate of 100% and 30-day mortality of 0% in 25 high-risk patients is encouraging. Technological and procedural improvements as well as increasing experience likely share responsibility for these improving outcomes.

Although mortality was not observed, morbidity was. The major source of morbidity was related to vascular access. Pre-procedural screening and improved vascular management appear to be reducing vascular morbidity and mortality risk (4). Consequently, a major thrust of current development is to reduce the diameter of the valve and delivery system. The development of a new, thinner cobalt-chromium SAPIEN XT valve frame with a more open design allows for tighter crimping of the valve and an improved delivery profile. Further modification of the delivery system to accommodate this next-generation valve is expected to reduce the delivery profile to 18- or 19-F (Fig. 5). Such a reduction in profile will likely increase the population of patients amenable to this therapy and improve outcomes further. The thinner struts of the next-generation cobalt-chromium low-profile device did not appear to result in a reduction in orifice area (Fig. 6). We have not observed structural valve failure in our larger experience with almost 200 valve implants. Comparable or improved durability with the next-generation valve is anticipated by in vitro testing but remains to be clinically demonstrated.

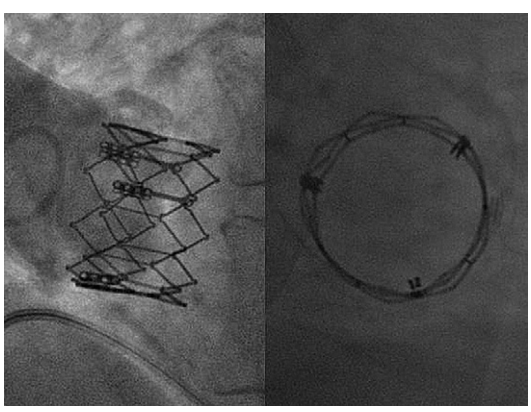

Figure 6 Fluoroscopic Appearance of the Low-Profile Cobalt-Chromium Next-Generation SAPIEN XT Valve

Aortic angiography shows optimal positioning with no evidence of paravalvular regurgitation **(left)**. The valve can be seen to be fully and symmetrically expanded **(right)**.

Conclusion

Advances in transcatheter valves, delivery systems, and procedural technique may result in improved outcomes and suggest the potential for a broader role of this therapeutic modality.

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Key Words: aortic stenosis ■ percutaneous ■ valve ■ valvuloplasty.