Transapical implantation of a self-expanding aortic valve bioprosthesis — animal feasibility study

Arie-Pieter Kappetein a,*, Nicolo Piazza b, Jean-Claude Laborde c, Peter P. de Jaegere b, Patrick W. Serruys b

a Department of Cardio-Thoracic Surgery, Erasmus Medical Center, Thoraxcenter, Rotterdam, The Netherlands
b Department of Interventional Cardiology, Erasmus Medical Center, Thoraxcenter, Rotterdam, The Netherlands
c Department of Interventional Cardiology, Clinique Pasteur, Toulouse, France

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Abstract

Background: Severe peripheral arterial disease may pose a limitation to the applicability of trans-arterial aortic valve implantation in patients who are otherwise candidates. For this reason, transapical aortic valve implantation has been proposed as a possible alternative. Objective: To evaluate the acute safety and performance of a specially designed delivery system, the CoreValve TranzapTM delivery catheter, for the transapical implantation of a self-expandable aortic valve prosthesis in a porcine animal model. Methods: Thirteen pigs were implanted with a self-expandable aortic valve bioprosthesis using a 21F catheter delivery system through a transapical approach. The delivery system was evaluated for: (1) the ability to access the implantation site; (2) the ability to precisely position the delivery catheter; (3) control of the delivery of the prosthesis; (4) safe retrieval of the delivery catheter; and (5) the ability to close the apical access site of the heart. Results: Successful implantation was achieved in 100% of the cases. The following points were achieved in all animals: (1) passage of the delivery catheter through an incision in the left ventricular apex; (2) positioning of the delivery catheter on the implantation site; (3) controlled deployment of the aortic valve prosthesis; (4) the safe retrieval of the delivery catheter system; and (5) the adequate closure of the apex of the heart. Conclusion: This study demonstrates the acute safety and feasibility of the CoreValve TranzapTM delivery system for the transapical implantation of the CoreValve self-expanding aortic valve bioprosthesis in a porcine animal model.

Keywords: Heart valve; Bioprosthesis; Cardiac catheterisation/intervention

1. Introduction

The goal of transcatheter implantation of the aortic valve is to provide patients with valve disease a therapy that is less invasive and will reduce morbidity and mortality. In 1992, Andersen et al. proposed the initial concept of a catheter-mounted, bioprosthetic aortic valve prosthesis for trans-arterial implantation [1,2]. A decade later, Cribier et al. translated this idea from bench to bedside for the first time [3]. Transarterial implantation of the aortic valve has become a viable option for patients with symptomatic severe aortic stenosis who are too sick to undergo conventional aortic valve replacement. However, peripheral arterial disease may pose a limitation to trans-arterial aortic valve implantation. For this reason, transapical implantation of the aortic valve has been suggested as an alternative.

The transapical approach entails access through the left ventricular apex for means of approach to the aortic valve annulus. Previous studies in swine have documented the feasibility of the transapical route for the antegrade implantation of a balloon-expandable valve composed of a stainless steel frame and equine pericardium [4–6]. Following these animal experiments, safety and feasibility studies in humans using the Edwards SAPIEN transapical system have shown encouraging results [7–11]. The objective of this study was to evaluate the acute safety and performance of a specially designed delivery system, the CoreValve TranzapTM delivery catheter, for the transapical implantation of a self-expandable aortic valve bioprosthesis in a porcine animal model.

2. Materials and methods

2.1. Aortic valve prosthesis

The aortic valve prosthesis used in the current study is identical to the device that has obtained the CE mark approval for trans-arterial implantation [12]. The prosthetic
Transapical implantation of a self-expanding valve consists of a self-expandable multi-level frame composed of nitinol to which is mounted a porcine pericardium heart valve in a trifoliate configuration. A skirt of pericardium at the inflow portion of the valve opposes against the aortic valve annulus and functions to mitigate perivalvular leakage. The function or durability in vivo of the aortic valve bioprosthesis has already been a subject of previous clinical studies and therefore was not evaluated in the current study.

2.2. Delivery catheter

The CoreValve Tranzap™ delivery catheter is specifically designed for the antegrade implantation of a self-expanding aortic valve prosthesis through a transapical approach. More specifically, the Tranzap™ CoreValve ReValving System™ is to be implanted during a minimally invasive surgical procedure using a small anterolateral thoracotomy. The delivery catheter is 21F at the distal end that hosts the compressed valve and is in contrast to the third-generation trans-arterial delivery catheter that is 18F.

3. Loading system

Prior to loading the prosthesis onto the delivery catheter, the prosthesis was rinsed in saline baths (three baths, 8 min each). Similar to the CoreValve trans-femoral approach, a five-piece disposable loading system is used to manually load the valve onto the delivery catheter. Assembling of the delivery system for purposes of antegrade deployment requires the prosthetic valve to be mounted onto the delivery catheter in an orientation opposite to that usually required for retrograde deployment. However, deployment of the valve within the aortic root follows the same principles as the trans-arterial approach, that is, the inflow portion of the device is released first (Fig. 1).

3.1. Animal model

Although the sheep model has been used commonly for valve testing [13], the porcine animal model was selected for the purposes of this study. The left ventricle of the sheep model is very sensitive to the direct contact with guide wires and catheters and can lead to lethal arrhythmias. In contrast, pigs show significant resistance to arrhythmias even when catheters are placed in the left ventricle through a transapical approach. Other pre-clinical experiments of transcatheter aortic valve implantation have used porcine animal models [4–6,14,15].

In contrast to the anatomy of the aortic valvar complex of humans, the porcine animal has: (1) a radius of curvature of the aortic arch that is significantly smaller; (2) the length of the aortic root and the ascending aorta is shorter; (3) the distance between the annulus of the aortic valve and the aortic leaflet of the mitral valve is reduced to less than 3 mm.

Previous studies in the porcine animal model have shown that migration following implantation of the aortic valve prosthesis can occur frequently. Space limitations within the root of the aorta for the self-expanding prosthesis lead to poor seating of the valve and consequent poor anchoring capabilities. Therefore, the stability of the implant or absence of migration was not assessed in the current study and has been a subject of study in previous clinical investigations.

Furthermore, the relatively short aortic root and ascending aorta cannot fully accommodate the end of the delivery catheter system that is 8 cm in length. As a result of this, evaluation of the adequate placement of the aortic prosthesis across the annulus of the aortic valve was not assessed. Instead, the catheter delivery system was delivered through the apex of the heart and across the brachiocephalic trunk such as to position the delivery catheter in a straight line rather than across the arch and being angulated.

3.2. End points

The delivery system was evaluated for: (1) the ability to access the implantation site; (2) ability to precisely position the delivery catheter; (3) control of the delivery of the prosthesis; (4) safe retrieval of the delivery catheter system; and (5) the ability to close the access site.

3.3. Experimental group and protocol

From December 2006 to February 2007, 13 pigs (weight 45–55 kg) were implanted with a self-expandable aortic valve bioprosthesis using the Tranzap™ 21F catheter delivery system through a transapical access site. All procedures were performed in a single laboratory of study (Paris, France). A team consisting of interventional cardiologists, a cardiac surgeon, a clinical specialist from CoreValve, veterinarians and an anaesthesiologist performed the procedures. Adhering to the ‘Guide for the Care and Use of Laboratory Animals (revised 1996)’ ensured proper care of the animals.

The animals were anaesthetised and received assisted mechanical ventilation. The right femoral artery was accessed and a graduated pigtail catheter was advanced to the ascending aorta. Measure of the diameter of the aortic root at the level of the basal hinge point of the aortic valve leaflets and the distance between the basal hinge point of the aortic valve leaflets and the first bifurcation was achieved by quantitative angiographic measurements during contrast aortography. A full sternotomy allowed visualisation of the apex of the heart. An 18-gauge needle was used to access the

![Fig. 1. Model of the Tranzap™ delivery catheter system. Part (A) shows unsheathing of the delivery catheter system (no valve is mounted). Part (B) demonstrates initial expansion of the valve prosthesis occurs from the proximal aspect of the covering sheath and from the inflow portion of the valve (in contrast to the trans-arterial delivery system where the initial expansion of the valve occurs from the distal aspect of the covering sheath) and that expansion begins.](https://academic.oup.com/ejcts/article-abstract/36/5/813/406686/Transapical-implantation-of-a-self-expanding)
apex of the left ventricle through a 2/0 purse-string suture technique (Prolene 2/0). An exchange guidewire (0.035 in.) was advanced through the needle into the left ventricle, across the native aortic valve and positioned in the brachiocephalic trunk (Fig. 2A). The 21F delivery catheter was advanced over the wire across the apex of the heart and up to the brachiocephalic trunk (Fig. 2B). Under fluoroscopic guidance, radio-opaque markers facilitated precise positioning of the delivery catheter within the aorta. Pushing the protective sheath distally deployed the self-expanding aortic prosthesis (Fig. 2C—E). Safe retrieval of the delivery catheter required closing of the working end of the catheter accomplished by pushing the internal portion of the delivery catheter distally through the valve and up to the sheath (Fig. 2F). The closed catheter was then retrieved across the deployed valve and through the apex of the heart (Fig. 2G). After retrieval of the guidewire from the access site, haemostasis was accomplished with the purse-string sutures. Animal euthanasia was performed after less than 1 h.

### 4. Quantitative angiography

Using a calibrated pigtail, the aortic valve annulus was measured at the level of the basal attachment point of the aortic valve leaflets, and the length of the ascending aorta was measured from the level of the sinutubular junction to the ostium of the right brachiocephalic artery (CAAS 5.0, Pie Medical, Maastricht, the Netherlands). These measurements served only as a guide to the feasibility for implantation.

### 5. Statistics

Continuous data are presented as mean ± standard deviation.

### 6. Results

The average measurement of the diameter of the aortic root at the level of the basal hinge point of the aortic valve leaflets was 22 ± 3 mm and the average length of the aortic root in addition to the ascending aorta was 56 ± 7 mm. Successful implantation of the self-expanding aortic valve bioprosthesis was achieved in all 13 porcine animal models (Table 1). The results demonstrate that accessing the implantation site could be achieved safely and repeatedly. Furthermore, fluoroscopy enabled excellent visualisation of the catheter and compressed aortic valve prosthesis during advancement through the left ventricular apex and across the native aortic valve. Adequate control of the delivery catheter of the aortic valve prosthesis was achieved in all cases. In addition, retrieval of the closed delivery catheter system...
across the apex of the heart was uneventful. In particular, migration or damage to the deployed aortic valve prosthesis, damage to the components of the mitral valvar complex (leaflets and chordae) and damage to the access puncture site were not observed. The purse-string sutures achieved haemostasis without any leakage — blood loss was minimal.

There was no evidence of coronary occlusion on final contrast aortography or myocardial ischaemia during intra-procedural electrocardiogram (ECG) monitoring. In all cases, haemodynamic stability was maintained during the implantation procedure.

7. Discussion

The following points were achieved in all animals: (1) passage of the delivery catheter through an incision in the left ventricular apex; (2) positioning of the delivery catheter on the implantation site; (3) controlled deployment of the aortic valve prosthesis; (4) the safe closing and retrieval of the catheter; and (5) the adequate closure of the apex of the heart.

This animal feasibility study provides the basis for the application of the Tranzap™ CoreValve ReValving System in humans.

In a European single-centre study of 50 patients undergoing transapical implantation with the SAPIEN prosthetic heart valve, the 30-day mortality rate was only 8% and the rate of conversion to conventional sternotomy was 6% [10]. In a European multicentre safety and feasibility study of 59 patients undergoing transapical implantation with the SAPIEN prosthetic heart valve, the in-hospital mortality rate in a high risk patient population was 13.6% and the rate of conversion to traditional sternotomy was 6% [10].

8. Limitations

This was an acute animal study examining a novel delivery catheter system. For reasons stated above, adequate placement of the device across the annulus of the aortic valve, functionality of the device and absence of migration were not assessed. Nonetheless, these end points have been previously evaluated.

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References


