Clinical experience with the ATS 3f Enable® Sutureless Bioprosthesis☆,☆☆

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Abstract

Objective: The ATS 3f Enable® Bioprosthesis is a self-expanding valve with a tubular design that allows for decreased leaflet stress and preservation of aortic sinuses. We report the midterm results of a prospective, multicenter clinical study evaluating the safety and efficacy of this stented bioprosthesis in patients undergoing isolated aortic valve replacement with or without concomitant procedures. **Methods:** A total of 140 patients (mean age: 76 ± 6 years; 63% of patients in New York Heart Association (NYHA) stage III—IV) received the ATS 3f Enable® Bioprosthesis in 10 European centers between March 2007 and December 2009. The total accumulated follow-up is 121.8 patient-years. **Results:** Valve implantation resulted in significant improvement of patients' symptoms. Mean systolic gradient was 9.04 ± 3.56 and 8.62 ± 3.16 mmHg with mean effective orifice area of 1.69 ± 0.52 and 1.67 ± 0.44 at 6 months and 1 year, respectively. No significant transvalvular aortic regurgitation was observed. Early complications included three major paravalvular leaks (PVL; 2.1%) resulting in valve explantation and one thrombo-embolic (0.7%) event. All, but one, of the early PVLs were evident intra-operatively with the medical decision made not to reposition or resolve immediately. Late adverse events included three explantations (2.5% per patient-year): one due to PVL and two due to endocarditis. There was an additional case of late endocarditis (0.8% per patient-year) that resolved by medical management. No structural deterioration, valve-related thrombosis or hemolysis was documented. **Conclusions:** The sutureless valve implantation technique is feasible and safe with the ATS 3f Enable Bioprosthesis. Valve implantation resulted in excellent hemodynamics and significant clinical improvement. Overall, these data confirm the safety and clinical utility of the Enable® Bioprosthesis for aortic valve replacement.
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Keywords: Bioprosthesis; Stented; Sutureless; Prospective clinical trial

1. Introduction

Degenerative valvular diseases, including aortic valve stenosis (AS), represent a growing health-care issue around the [1] globe. Surgical replacement of the aortic valve (AVR) is the only treatment modality that consistently increases survival rates in case of hemodynamically significant orifice narrowing [2]. Historically, AVR has been contraindicated in elderly and high-risk patients because of the negative effects of full sternotomy, cardiopulmonary bypass and cardioplegic arrest. However, with recent advances in minimally invasive approaches, such as partial sternotomy and the development of novel bioprostheses, an increasing number of high-risk subjects are being considered for surgical management [3—5]. Of note, reducing surgical trauma by smaller incision proved to be highly beneficial despite the fact that minimally invasive techniques are often associated with impaired visualization of the aortic root and may prolong cardiopulmonary bypass and cross-clamp times, at least during the surgeon's initial learning curve [5,6]. For implantation through minimally invasive approaches, and with the intention to shorten long multi-target procedures, sutureless bioprostheses merit special interest.

The increasing demand for bioprostheses with limited surgical burden, yet with excellent hemodynamic profile, prompted the development of the ATS 3f Enable® Model 6000 (ATS Medical Inc., Minneapolis, MN, USA) 'sutureless' valve. The basic structure of the valve is identical to its predecessor,

the ATS 3f® Aortic Bioprosthesis Model 1000 (ATS Medical Inc., Minneapolis, MN, USA), but a nitinol frame has been added allowing for sutureless implant [7,8].

The first clinical results with the early version of the new ATS 3f Enable® Aortic Bioprosthesis Model 6000 sutureless valve were reported by Wendt et al. in 2008 [9]. After careful review of this initial data, modifications to the flange were performed resulting in the second generation of the valve [10]. To evaluate the safety and clinical performance of the bioprosthesis, a prospective, multicenter clinical trial was initiated. Single-center experiences were published in 2009 and 2010 [10–12]; the minimally invasive approach using partial sternotomy was first reported in 2010 [13]. It is the objective of this report to present the intermediate data of this prospective, multicenter clinical study enrolling patients at 10 European investigational sites.

2. Patients and methods

2.1. Device description

The device is assembled from three equal sections of equine pericardial tissue using locking sutures (Fig. 1). The interlocking, adjacent leaflets form a tubular structure and result in three, equally spaced commissural tabs that are reinforced with polyester material. All equine tissues are pre-treated with glutaraldehyde under specific conditions (e.g., critical treatment time, pH, and temperature). This fixation process preserves the architecture of the collagen matrix thus maintaining tissue strength and flexibility, minimizes immunogenicity and reduces thrombogenic potential [7,8]. A self-expanding nitinol frame covered with polyester fabric on the inflow aspect has been added to the design of the ATS 3f Enable® Model 6000 bioprosthesis. The internal properties of nitinol and the flexibility of the pre-treated equine pericardial leaflets allow the device to be folded and to be positioned appropriately within minutes intra-operatively. Upon deployment, its shape and size return to the preset dimensions and the outward radial forces inherent to the thermal memory of the nitinol frame keep the valve fixed at the target position, preventing it from migration. As such, only a single guiding suture, if any, may be necessary to secure the valve to the annulus. The polyester flange at the inflow aspect promotes tissue ingrowth and thus contributes to the long-term stabilization of the valve.

2.2. Patient population

A total of 140 patients (53 males, 87 females; mean age: 76.1 ± 5.7 years) were enrolled into this prospective, international, multicenter, non-randomized study. Participants were implanted with the novel ATS 3f Enable® Sutureless Bioprosthesis between March 2007 and December 2009 at one of the 10 participating European investigational sites: (1) Johann Wolfgang Goethe University (Frankfurt, Germany); (2) Jagiellonian University (Krakow, Poland); (3) University Hospital Bern (Bern, Switzerland); (4) John Radcliffe Hospital (Oxford, UK); (5) UKSH, Campus Lubeck (Lubeck, Germany); (6) University Medical Center Freiburg (Freiburg, Germany); (7) Medical University of Gdansk (Gdansk, Poland); (8) University Medical Center Kiel (Kiel, Germany); (9) Medical University Vienna (Vienna, Austria); and (10) University Hospital Basel (Basel, Switzerland).

Patients requiring isolated AVR with or without concomitant procedures were eligible to participate. Patients requiring valve replacement other than the aortic valve, subjects with previously implanted prosthetic heart valve(s,) and/or rigid annuloplasty ring in the mitral position were excluded from the study. Preoperative exclusion criteria included active endocarditis or other systemic infections; pathologies potentially leading to irregular geometry of the ascending aorta, and life expectancy less than or equal to 24 months at the time of the surgery. Patients younger than 20 years of age, those not willing to return to the implant center to complete the required follow-up visits, alcohol and/or intravenous-drug abusers, and those who participated in concomitant research studies of investigational products were also excluded. Additional intra-operative exclusion criteria included abnormal anatomy of the coronary ostia at high risk for occlusion by the study device, active endocarditis, and the need for rigid annuloplasty ring implantation at the mitral position.

The study was conducted according to the applicable local and international regulatory requirements and was approved by the local Ethics Committee at each investigational site. All patients enrolled in the study were informed adequately regarding the investigational status of the device, the associated benefits and risks, and the availability of

Fig. 1. Photo of the ATS 3f Enable® Aortic Bioprosthesis Model 6000.

alternative treatment options. A written informed consent was obtained from all participants.

2.3. Procedure

Complete median sternotomy was performed for 112 patients (80%); 28 subjects (20%) underwent partial upper sternotomy (a less invasive approach). Following cardiopulmonary bypass and cardioplegic arrest, the aortic valve was exposed through transverse aortotomy and the native valve was excised under direct observation. The ATS sutureless bioprosthesis was positioned and deployed at the target location. A detailed description of the entire surgical procedure has been published previously [11]. Intra-operative transesophageal echocardiogram (TEE) was routinely performed to verify correct valve positioning and to assess the hemodynamic performance of the valve.

2.4. Follow-up

Patient safety and the performance of the ATS 3f Enable® Model 6000 Bioprosthesis were assessed through regularly scheduled follow-up visits. A complete physical examination, routine chemistry panel, and TTE were performed at the time of hospital discharge, at 3—6, 11—14 months post-surgery, and annually thereafter. Hemodynamic parameters were assessed via TTE by two-dimensional, M-mode, pulsed-wave and color-flow imaging. All echocardiographic data were forwarded to an independent core laboratory. Adverse events were reported as 'early' if detected within 30 days of surgery and 'late' if documented subsequently.

2.5. Statistical analysis

Descriptive statistics are presented for baseline demographic, clinical, and operative parameters. Hemodynamic parameters were expressed as mean ± standard deviation. Estimates for both early (within 30 days of the implant procedure) and late (greater than 30 days post implant) adverse events are provided. Early adverse event rates were calculated by dividing the number of events by the total number of patients. Late adverse event rates were expressed as linearized rates and were calculated by dividing the number of events by the length of follow-up in patient-years. Kaplan—Meier estimates for cumulative survival from valve-related mortality and total mortality at 1 year are presented. Change in NYHA class was tested for statistical significance using a paired t-test. All analyses were conducted using SAS version 9.2 (SAS Institute, Cary, NC, USA).

3. Results

3.1. Patient and procedure characteristics

Patient demographics and operative details are summarized in Tables 1 and 2. The indication for the surgery included degenerative native aortic valve disease (113 patients; 80.8%); rheumatic heart disease (24 patients; 17.1%); abnormality related to prior endocarditis (one patient; 0.7%), and other aortic valve pathology (two patients;

Table 1. Pre-operative patient demographics.

Variable	Category	Study cohort	
		$n = 140$	
Age at implantation (years)		76.1 ± 5.7	—
Body mass index (BMI)		28.3 ± 4.7	—

Variable	Category	N	%
Gender	Male	53	38
	Female	87	62
Previous cardiac surgery	Yes	29	21
	No	111	79
Valvular lesion	Stenosis	99	71
	Insufficiency	5	4
	Mixed	36	26
Pre-existing medical conditions	Angina	21	15
	Cardiac arrhythmia	37	26
	Cardiomyopathy	5	4
	Carotid artery disease	24	17
	Coronary artery disease	77	55
	Diabetes mellitus	43	31
	History of endocarditis	2	1
	Hyperlipidemia	64	46
	Hypertension — pulmonary	22	16
	Hypertension — systemic	120	86
	Mitral insufficiency	32	23
	Obesity	29	21
	Smoking	26	19
	TIA	6	4
	Chronic obstructive lung disease	20	14
	Tricuspid insufficiency	13	9

1.4%), as indicated in Fig. 2. The total accumulated follow-up was 121.8 patient-years, as of the cut-off date for the present report.

Implantation of the ATS 3f Enable® Model 6000 Bioprosthesis was successful using only a single guiding suture in 85.6% of patients. Mean aortic cross-clamp and cardiopulmonary bypass times were noted as 58.1 ± 25.1 and 84.9 ± 34.2 min, respectively. Two of the centers reported average cross-clamp and cardiopulmonary times as low as 36.8 ± 7.7 and 54.8 ± 11.5 for their stand-alone procedures ($n = 34$). Concomitant procedure was performed for 42 patients (30% of all study participants), with coronary artery bypass grafting (18.6%) and left atrial appendage closure (3.6%) being the most frequent. The following sizes were used in the present study: 19 mm (four patients), 21 mm (37 patients), 23 mm (42 patients), 25 mm (36 patients), 27 mm (16 patients), and 29 mm (five patients).

3.2. Early and late adverse events

Five patients (3.6%) died within 30 days of surgery; two of these deaths were classified as valve related (1.4%): one participant died of multi-organ failure and one of bi-ventricular heart failure. Of note, both deaths were classified as events with unknown etiology by the Principal Investigators, thus leading to the automatic re-classification of these events as valve related. Early non-fatal adverse events were limited to cerebrovascular accident in a single patient (0.7%), major paravalvular leak (PVL) prompting valve explantation

Table 2. Operative patient demographics.

Variable	Category	Total population	
		n = 140	%
Exposure techniques (sternotomy)	Conventional sternotomy	112	80
	Minimally invasive sternotomy	27	19
	Other	1	1
Opening of the aorta (aortotomy)	Complete aortic transection	5	4
	Partial aortic transection	135	96
Concomitant procedures (data are not mutually exclusive)	None	98	70
	Coronary artery bypass	26	19
	Left atrial appendage closure	5	4
	Annuloplasty	1	1
	Subvalvular myectomy	6	4
	Left atrial ablation	4	3
	Aortic surgery	3	2
Cardioplegia	Cold	112	80
	Warm	0	0
	Both	28	20
Cardioplegia delivery	Antegrade	103	74
	Retrograde	2	1
	Both	35	25
Condition of ascending aorta	Normal	112	80
	Calcified	14	10
	Dilated	14	10
Condition of annulus (data are not mutually exclusive)	Normal	11	8
	Calcified	126	90
	Fibrotic	20	14
	Friable	3	2
Extent of debridement	None	1	1
	Minimum	6	4
	Moderate	48	34
	Average	68	49
	Extreme	17	12
Subvalvular aortic stenosis	None	127	91
	Dynamic	1	1
	Idiopathic hypertrophic subaortic	10	7
	Indeterminate	2	1
Number of sutures (n = 139)	0	17	12
	1	119	86
	2 or more	3	2

in three subjects (2.1%), and minor PVL not requiring surgical intervention in three patients (2.1%). All, but one early PVLs were evident intra-operatively, but the medical decision was made by the surgical team not to reposition the bioprosthesis or resolve the leak by other means immediately.

Thirteen patients died in the late postoperative period; a valve-related cause was identified in two of these subjects (1.6% per patient-year; both sudden cardiac deaths). Cumulative freedom from valve-related mortality was

Fig. 2. Indication for surgery in our study population (n = 140).

96.5% at 1 year and freedom from total mortality was 85.1% during the same reporting period. Late adverse events included major PVL in one patient prompting valve explantation (0.8% per patient-year). Endocarditis was diagnosed in three cases (2.5% per patient-year); among those patients, valve explantation was unavoidable for two subjects, while the third patient was managed medically and responded well to the therapy. No structural prosthetic deterioration, valve thrombosis, hemolysis, or clinically significant transvalvular aortic regurgitation occurred during the follow-up period.

3.3. Hemodynamic parameters

TTE was performed and hemodynamic parameters were obtained at the time of hospital discharge and at regularly scheduled outpatient visits at 3—6 and 11—14 months post-surgery. Echocardiographic results are presented in Table 3. The average mean aortic gradient was measured at 10.2 mmHg at the time of discharge, 9.0 at 3—6 months, and 8.6 mmHg at 11—14 months. Accordingly, the average
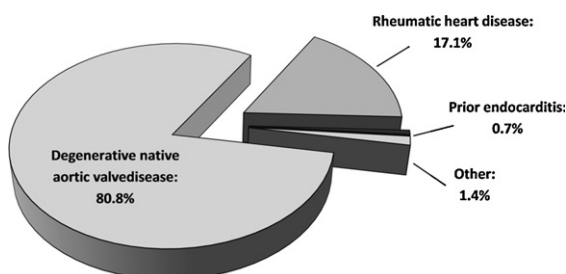
Table 3. Hemodynamic parameters during the study period, as measured by transthoracic echocardiography.

|	Discharge	Post-implantation	
		3—6 months	11—14 months
Mean gradient (mmHg)	10.24 ± 4.20	9.04 ± 3.56	8.62 ± 3.16
Peak gradient (mmHg)	20.34 ± 8.15	18.21 ± 6.89	16.44 ± 6.00
Effective orifice area (cm^2)	1.75 ± 0.45	1.69 ± 0.52	1.67 ± 0.44
Indexed effective orifice area (cm^2/m^2)	0.98 ± 0.26	0.92 ± 0.28	0.92 ± 0.24
Left ventricular cardiac output (l/min)	5.20 ± 1.16	4.57 ± 1.11	4.48 ± 1.00
Left ventricular cardiac index (l/min m^2)	2.92 ± 0.65	2.51 ± 0.66	2.47 ± 0.60
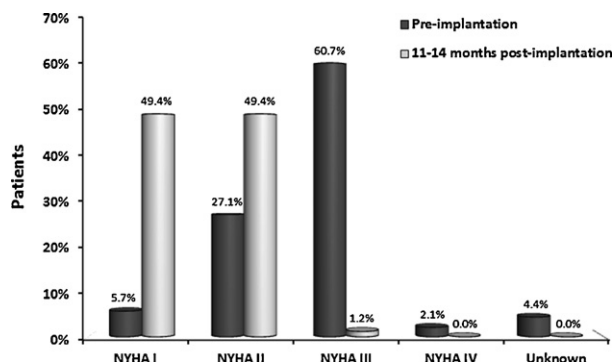
Fig. 3. The effect of aortic valve replacement with the ATS 3f Enable® Aortic Bioprosthesis Model 6000 on the New York Heart Association (NYHA) functional capacity. Pre-operative and 11—14 months post-operative data are shown. The improvement in the NYHA functional classification is highly significant at $p < 0.0001$.

peak systolic gradient decreased from 20.3 to 18.2 mmHg and then to 16.4 mmHg by the end of the first postoperative year. The following parameters were also measured and the average values at the time of discharge, 3—6, and 11—14 months follow-up visits were collected: effective orifice area (1.75 ± 0.45 vs 1.69 ± 0.52 vs 1.67 ± 0.44 cm^2); indexed effective orifice area (0.98 ± 0.26 vs 0.92 ± 0.28 vs 0.92 ± 0.24 cm^2 m^{-2}); cardiac output (5.20 ± 1.16 vs 4.57 ± 14.11 vs 4.48 ± 1.00 l min^{-1}); cardiac index (2.92 ± 0.65 vs 2.51 ± 0.66 vs 2.47 ± 0.6 l min^{-1} m^{-2}).

3.4. Effect of AVR on the New York Heart Association (NYHA) functional capacity

The NYHA functional capacity was evaluated and recorded preoperatively and at all subsequent visits. As shown in Fig. 3, more than 62% of patients were categorized as NYHA Class III or IV at the pre-implantation assessment and merely 5.7% fell in the Class I group. By contrast, 98.8% of patients reported NYHA Class I and II symptoms at the 1-year follow-up visit, with only a single patient remaining symptomatic at minimal activity (Class III). These data represent a significant ($p < 0.001$) improvement in the functional capacity of most patients undergoing AVR with the ATS 3f Enable® Model 6000 Aortic Bioprosthesis.

4. Discussion

The excellent operative results obtained with stented and stentless bioprosthetic valves to treat severe aortic stenosis in the elderly population promote their broad usage.

Implantation of a stented valve is technically less demanding and the hemodynamic advantage of stentless valves are yet controversial with regard to the postoperative transprosthetic gradient and regression of the left ventricular hypertrophy [15]. As such, surgeons who would prefer the performance of a stentless valve may be dissuaded from its use because of the technical difficulty and extra surgical time required by some models. Thus, there is an ongoing effort to develop and evaluate novel devices and surgical techniques for the management of these high-risk patients. The present report summarizes the results of a multicenter, international, prospective clinical trial with the ATS 3f Enable® Model 6000 Aortic Bioprosthesis, the first commercially available sutureless bioprosthesis for conventional AVR. Ten European investigational sites participated in the study, which was conducted before CE approval in 2010.

The idea of a sutureless valve in the aortic position was first introduced by McGovern et al. in the early 1960s; they presented clinical results with a ball-cage-type mechanical valve [16]. The high incidence of disabling thromboembolism (42%) and re-operation (16%), however, precluded the routine adaptation of these early models [17]. Forty years later, Wendt and colleagues published the initial clinical experience with the novel, ATS 3f Enable® Aortic Bioprosthesis developed for sutureless implantation [9]. In their early experience, three out of six patients presented with paravalvular leak at follow-up visits. Because of this unfavorable observation, the initial design was modified and the inferior aspect of the polyester flange was enlarged allowing for broader interface with the annulus. In addition, the need for three 'stay sutures' was eliminated, which may have caused distortion of the implant. These structural changes led to a dramatic reduction in the incidence of paravalvular leak; however, exact positioning of the ATS 3f Enable® Aortic Bioprosthesis remains critical.

The self-expanding nature of the nitinol frame has the potential to facilitate faster deployment and valve implantation. The bypass and aortic cross-clamp times reported in the present series are shorter, but not statistically different from those reported for other stented bioprostheses [15,18,19]. It is important to note, however, that procedural time relates inversely with the experience of the surgical team, and data from experienced centers indicate that the above times can be significantly reduced to as low as 36.8 ± 7.7 and 54.8 ± 11.5 min for stand-alone procedures, respectively. In our opinion, additional modifications to the polyester flange allowing for broader coaptation with the native annulus and enhanced positioning of the valve would further reduce procedural time. In addition, a minimally invasive approach via partial upper sternotomy is feasible with the

ATS 3f Enable® Aortic Bioprosthesis in patients without the need for additional procedures. This was indeed the access of choice in approximately one-fifth of all enrolled patients and yielded good results.

In our hands, the valve proved to be versatile and has demonstrated good intra-operative handling characteristics. Early hemodynamic data are encouraging and are comparable with conventional stented valves [15,18—22]. The effective orifice area, indexed effective orifice area, cardiac output, and cardiac index exhibited a slight decrease over the follow-up period, which is consistent with reports on other stented valves [18—22]. Of critical importance, a significant and persistent improvement was documented in the NYHA functional status of the majority of patients undergoing AVR with the ATS 3f Enable® Bioprosthesis.Early fatal complications were limited to 3.5%, including two valve-related and three non-valve related deaths. Early non-fatal complications were documented in 4.9% of the cohort. Late adverse events were recorded at 3.3% per patient-year during the follow-up period, and these included endocarditis and major PVL. An important lesson learned in this trial is that significant PVLs noted by intra-operative echocardiogram should always be treated during the index procedure. Patients leaving the operating room with good echocardiographic results are highly unlikely to develop PVL. The issue of PVL often associated with sutureless techniques has also been addressed by other groups working with a different device [23—25].

In addition, no structural prosthetic deterioration, valve thrombosis, mechanical hemolysis, or significant transvalvular aortic regurgitation occurred during the study period. Cumulative freedom from valve-related mortality was 96.5% at 1 year. As noted in Table 2, no suture was applied in 17 cases and only a single guiding suture was used in 119 of the 140 participants. However, no valve migration (movement of the valve from its original locus) or tilting was noted post-implantation. Given the unique design of the bioprosthesis, ostial blockage of the coronary arteries was not documented. In the present study, surgical complications and adverse event rates were comparable to those observed with any other commercially available stented aortic valves [18—22]. The long-term durability of the valve in the clinical setting is yet to be determined.

Interest in less invasive valve procedures is primarily driven by the expected benefit for the patient, including achievement of the same quality of treatment with reduced operative mortality and morbidity. Besides the possible facilitation of minimally invasive approaches, this valve may also be advantageous for patients needing AVR replacement along with concomitant procedures that prolong cardiopulmonary bypass and aortic cross-clamp times, such as coronary artery bypass grafting.

Catheter-based aortic valve implantation is a new technique developed for high-risk patients not suitable for conventional cardiac surgery. Sutureless valve implantation via partial sternotomy may be considered in this population, especially if clinical follow-up data confirm the encouraging initial results described here and cross-clamp times can be reduced with increasing experience. Potential advantages versus the catheter-based techniques include the direct view of the aortic valve enabling its complete resection,

decalcification of the aortic annulus, and the safe placement of the new implant under direct visualization. On the contrary, cardiopulmonary bypass and cardioplegic arrest are unavoidable with this approach. Further large case clinical studies will be required to compare the safety, efficacy, and long-term outcome of the two methodologies.

In summary, the ATS 3f Enable® Model 6000 Aortic Bioprosthesis has a safe clinical profile combined with good and sustainable hemodynamics. Clinical improvement in virtually all patients' functional status is demonstrated and is in line with the observed hemodynamic performance. The primary benefit of this aortic bioprosthesis is the potential for surgeons to provide the same gold standard outcomes of traditional surgical AVR but without the need for sutures, thereby facilitating less invasive or minimally invasive procedures. Our multicenter study continues and documents the long-term performance, durability, and safety profile of this bioprosthesis.

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Appendix A. Conference discussion

Dr P. Suwalski (*Warsaw, Poland*): While reading the manuscript, what first came to my mind were the special indications applicable to this model of the valve. First of all, parasternal access, which can be quite difficult for standard sutured valves, or robotic surgery, for example, as shown during Techno College in very impressive work from our colleagues from the States, and narrow roots. Have you tried maybe those kinds of indications? Do you know any applications in this kind of surgery? That would be exciting to know about it. On the other hand, even 35 minutes of cross-clamp time is very comparable to sutured valves. In your experience, what was the main reason requiring that period of cross-clamping, and what would be the way to take it down to, let's say, 15 minutes?

Dr Martens: When presenting this data, there is always the discussion about why the cross-clamp time isn't shorter. The most important obstacle at the moment is the design of the current model, because it really requires exact placement in the annulus. And as you see on the screen, the newer model allows for easier implant because it has a broader surface area adapting to the annulus. That is also the answer to the question with regard to the minimally invasive approaches. We applied quite a lot of the Enable I valves via partial sternotomy, and what we found out is that visualization of the annulus is absolutely mandatory with this model. So to reduce the clamping time, we have to make the implant easier, allowing for setting it free without correcting the position afterwards.

And the other point is that we performed very meticulous debridement of the annulus. We are now discussing with the other centers who are implanting this valve if this is really necessary or if we should just cut out the leaflets and leave bigger parts of the annulus, perhaps with calcium. However, I think the low incidence of paravalvular leakage in the whole cohort is also caused by the fact that we debrided the annulus. But, on the other hand, that makes the implantation time longer. So it is the beginning of a discussion, but I absolutely agree with making the procedure suitable for a minimally invasive approach. This was, for example, also performed by Volkmar Falk's group in Zurich, where a surgeon implanted it via a parasternal approach. We also found out that it is feasible, but that the design of the valve should be changed, allowing for faster and easier implant.

Dr O. Alfieri (*Milan, Italy*): I would like to ask one question. In my experience, a little bit of a disadvantage of this is that you have to make your incision in the aorta, your aortotomy, a little bit higher, maybe 1 cm higher, and this, of course, is making the calcification of the annulus maybe a little bit more difficult, particularly minimally invasively. With the new model do have to make the incision as high or you can make your aortotomy a little bit lower?

Dr Martens: To answer this question, it is absolutely right, because you have to make the incision higher as in a normal aortic valve replacement procedure, and with the new model, which is not as high as the old one, you gain around 5 mm, so you can make the incision slightly lower than before. However, it is a higher incision than in a standard aortic valve replacement procedure. As I said before, there is an ongoing discussion whether this meticulous debridement is necessary with this valve, and we don't know the answer at the moment. For the study, for the 140 patients presented here, we performed the debridement, but now the discussion arises as to whether it is really necessary to this extent.

Dr Alfieri: Do you tolerate 1+ insufficiency in this valve? Did you notice a tendency to deterioration of the leaks over time?

Dr Martens: We learned that we shouldn't tolerate any paravalvular leakage in the OR. I wouldn't tolerate any. In the cases I performed in Frankfurt I haven't seen any, but we have learned from experience that a +1 aortic paravalvular regurgitation might increase over time, because the valve is not exactly positioned. In this situation I would convert the case or place a bigger valve. But I wouldn't allow the patient to leave the OR with a paravalvular leakage. We learned from the three early reoperations, where in two of these patients the paravalvular leakage was already seen in the OR, and the decision was taken not to go for a second pump run, and perhaps that decision wasn't good.

Dr P. Myken (*Gothenburg, Sweden*): I understand this study; if you go on to have robotic surgery or minimally invasive, it is a good valve to use. But if you continue to do conventional open surgery, would you prefer this valve instead of a sewing ring just for the 30 minutes and could you comment on your thoughts of durability?

Dr Martens: Well, we have durability data on the model which is the basis of this valve. The basis of this valve is the 3f valve, and we have long-term durability data on this valve now from quite a lot of centers. So as the basis is a standard valve which is already in clinical use, we think that putting it in a nitinol stent doesn't really change the long-term durability. However, we have to wait for long-term data, that's for sure.

To your question as to what might be the advantage versus other valves, I see an advantage. For example, I operated on quite a lot of patients with a small aortic annulus, and I haven't seen a comparable small valve which expands in the annulus and really results in a good orifice area and a low gradient in a small aortic annulus without performing surgery like root enlargement. So I really see the advantage of having a fast procedure and to obtain a good hemodynamic gradient, and the other point is to enable minimally invasive procedures.

Dr A. Bogers (*Rotterdam, The Netherlands*): All valve implants that depend on radial forces have an increased incidence of total heart block. How is this in your prosthesis?

Dr Martens: I didn't have the incidence in my slides. We had an incidence of permanent pacemaker implant in this patient cohort of 7%. So I would say it is slightly increased versus a standard procedure, but I think not comparable, for example, to transcatheter valves. So the incidence is 7% pacemaker implant.