

# Endoscopy in aortic valve repair: does it worth it?

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**Background:** Aortic valve repair (AVR) is a technically challenging procedure. Usually, the repaired valve is checked after weaning from cardiopulmonary bypass (CPB). We aimed to evaluate intraoperative and clinical outcomes of AVR patients in whom intraoperative aortic root endoscopy was applied.

**Methods:** The present study was a retrospective single-center study. An autoclavable video-scope was used to evaluate aortic valve. During endoscopy, crystalloid cardioplegia was administered to pressurize the aortic root. Primary endpoints were: need for Re-CPB after weaning from bypass and early postoperative aortic valve regurgitation. Secondary endpoints included: 30-day mortality and freedom from aortic regurgitation/reoperation during follow-up.

**Results:** A total of 66 consecutive patients who underwent AVR (05/2014–03/2017) were evaluated. Patients mean age was 53.5±14.5 years and 74.2% were male. Seventy-three percent of the patients were in New York Heart Association (NYHA) functional class III/IV. The main underlying aortic valve pathology was aortic valve regurgitation in 83.3%, 9.1% aortic stenosis and combination of both in 7.6%. A tricuspid or bicuspid aortic valve was observed in 48.5% and 43.9%, respectively, whereas 7.6% showed a functional unicuspid aortic valve. Intraoperative results revealed endoscopy as a helpful tool, where second time cross-clamp was avoided in most (58, 87.9%) of patients. Thirty-day mortality was 3.0%. During follow-up (28±10 months), 2 patients required re-operation due to recurrent aortic valve regurgitation.

**Conclusions:** The present analysis showed, that intraoperative aortic valve endoscopy is a helpful tool to evaluate AVR before weaning from bypass. This easy-to-use tool gives real-time information about the intraoperative result and might provide additional guidance to achieve optimal results after AVR.

**Keywords:** Aortic valve repair (AVR); aortic root endoscopy; “David” procedure

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## Introduction

Aortic valve repair (AVR) is a technically challenging procedure, where attention must be paid to all anatomic and dynamic components of the aortic valve. These components include the sinotubular and aortoventricular junction, the dimensions of the aortic annulus, as well as the integrity and geometry of the aortic valve leaflets. Due to this complexity,

many different techniques for AVR have been developed.

However, all these concepts inherit unsatisfactory conventional and quite subjective testing methods, such as a saline flush maneuver during cardioplegia-arrested heart. Moreover, final aortic valve function after repair can only be assessed by transoesophageal echocardiography (TOE) after weaning from cardio-pulmonary bypass. Insofar, an objective method to directly evaluate the repaired

aortic valve during cross-clamp would be advantageous. Therefore, we evaluated the repaired aortic valve by the use of autoclavable endoscope, which was placed above the aortic valve while administering cardioplegia into the aortic root to create an artificial pressure during testing.

The aim of the present analysis was to evaluate the intraoperative results and potential modifications of AVR by the use of this additional tool of root endoscopy.

## Methods

### Study design

The present study was a retrospective single-center evaluation, including 66 patients undergoing aortic root endoscopy during AVR between 05/2014 and 03/2017. The present study obtained IRB-approval according to the Declaration of Helsinki. The primary study end-points were: need for Re-CPB after weaning from bypass and early postoperative aortic valve regurgitation at discharge. Secondary study end-points were: 30-day mortality and freedom from aortic regurgitation and reoperation during active follow-up.

### Data collection and follow-up

Patient and operative demographics were recorded in a prospective institutional database and retrospectively extracted and evaluated. Perioperative deaths (30-day mortality) were tracked from the database or by active follow-up thereafter. Active follow-up was performed through December 2017 and was 100% complete. Active follow-up included: mortality, freedom from reoperation and degree of aortic regurgitation (last transthoracic echocardiography).

### Operative technique

All operations were carried out through a standard (partial) median sternotomy and cardiopulmonary bypass was performed (CPB) with ascending aorta cannulation and single two-stage atrial cannula or selective bicaval cannula depending in the concomitant procedure. A cannula was inserted at the junction of the right superior pulmonary vein for venting of the left ventricle. Moderate hypothermia (28–32 °C) was obtained. Myocardial protection was achieved by antegrade and optional retrograde crystalloid cardioplegic arrest (Custodiol®, Dr. Köhler Chemie, Bensheim,



**Figure 1** The rigid autoclavable video-scope (Olympus®) used for aortic root endoscopy.

Germany) and additional topic cooling. A hockey-stick aortotomy was performed. AVR was performed in patients presenting aortic stenosis, aortic valve regurgitation or combination of both using different techniques, such as aortic valve re-implantation, aortic valve re-construction by using either autologous or tissue engineered pericardium, as well as different complex aortic cusp repair techniques. When indicated, replacement of the ascending aorta was also performed. During cardioplegia-arrested heart after completed AVR, the operative result was directly evaluated: This was achieved by placing an autoclavable video-scope (rigid 0° scope, 5 mm diameter, WA50020B, Endo-Eye®, Olympus, Tokyo, Japan) (*Figure 1*) into the aortic root while the proximal aorta or the aortic vascular graft was clamped and crystalloid cardioplegia was administered to create an artificial blood pressure (~100 mmHg) within the aortic root. Moreover, while cardioplegia was administered, the left ventricle was simultaneously vented (*Figure 2*).

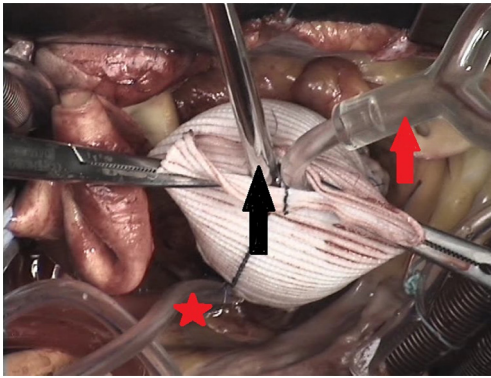
### Statistics

Continuous data were expressed as mean ± standard deviation (SD), and categorical data were expressed as percentages or frequencies. Survival curves and freedom from reoperation were generated with the Kaplan-Meier method. All statistical analyses were performed with the SPSS software (version 22.0, IBM Corp., Armonk, NY, USA). The authors had full access to the data and take full responsibility for the integrity of the data.

## Results

### Patient population

Mean age of the total group was 53.5±14.5 years (range, 22–76 years), 74.2% (n=49) were male, and 73% presented



**Figure 2** Intraoperative image showing the use of aortic root endoscopy. Tight closure of the aorta on the endoscopy and injection line, the red arrow refers to the pressurized (~100 mmHg) injection line. Endoscope is in the middle of the aorta (black arrow). The subannular purse string suture is seen (red star) which is used in our modified technique.

with New York Heart Association (NYHA) class  $\geq$  III. The pre-operative underlying pathology of the aortic valve was stenosis in 9.1% (6 patients), regurgitation in 83.3% (55 patients, of whom 4 presented with acute type A aortic dissection) and combination of both in 7.6% (5 patients). Demographics are presented in *Table 1*. Most of the patients (98.5%) presented with additional pathology of the ascending aorta (aneurysm or dissection).

### **Operative outcomes and primary study endpoints**

AVR was performed via aortic valve re-implantation (David procedure) in 45 (68.2%) patients, replacement of all three cusps using either autologous or tissue-engineered pericardium in 13 (19.7%) patients or complex aortic valve cusp repair in 8 (12.1%) patients, of whom seven received concomitant replacement of the ascending aorta. In total, replacement of the ascending aorta was performed in 97% of the patients. Concomitant procedures were performed in 68.2% of the patients: concomitant coronary bypass surgery in 8 (12.1%) patients, mitral valve repair in 5 (7.6%) patients, tricuspid valve repair in 2 (3.0%) patients, closure of patent foramen ovale in 16 (24.2%) patients. In 10 (15.1%) patients, various concomitant procedures were performed, such as subvalvular myectomy, left atrial appendage closure, or a MAZE procedure. Various cusp repair techniques (shaving, plication sutures, decalcification, bicuspidalisation, tricuspidalisation, raphe resection,

**Table 1** Baseline patient characteristics

Variable	All patients (N=66) (%)
<b>Demographics</b>	
Age, years	53.5 $\pm$ 14.5
Gender, male	49 (74.2)
BMI, kg/m <sup>2</sup>	27.9 $\pm$ 4.1
<b>Risk factors &amp; comorbidities</b>	
Peripheral vascular disease	2 (3.0)
Hypertension	60 (90.9)
COPD	10 (15.1)
Dialysis	5 (7.6)
Diabetes mellitus	10 (15.1)
Pulmonary hypertension	5 (7.6)
Smoking	32 (48.5)
Hyperlipidemia	29 (43.9)
Prior aortic valve repair	2 (3.0)
Acute type A aortic dissection	4 (6.1)
<b>Aortic valve morphology</b>	
Tricuspid	32 (48.5)
Bicuspid	29 (43.9)
Unicuspid	5 (7.6)
<b>LVEF</b>	
>50	57 (86.4)
30–50	6 (9.1)
<30	3 (4.5)
<b>Other combined cardiac disease</b>	
Mitral valve disease	5 (7.6)
Tricuspid valve regurgitation	2 (3.0)
Coronary heart disease	8 (12.1)
Patent foramen oval	16 (24.2)

Data are presented as mean  $\pm$  SD or number (%). BMI, body mass index; COPD, chronic obstructive pulmonary disease; LVEF, left ventricular ejection fraction; SD, standard deviation.

triangular or complete cusp resection for at least one cusp) were performed in 58 patients. *Table 2* summarizes all operative outcomes.

Apart of 8 patients, second time cross-clamp was avoided in most [58] of the patients whereas extra plication was

**Table 2** Operative, early and mid-term outcomes

Variable	All patients (N=66) (%)
Aortic valve re-implantation	45 (68.2)
Aortic valve re-construction	13 (19.7)
Complex aortic cusp repair	8 (12.1)
Cross-clamp time, min	119.2±30.5
CPB-time, min	168.2±41.9
Operation time, min	286.2±59.5
Need of second cross-clamp	8 (12.1)
Due to residual aortic regurgitation	6 (9.1)
Due to bleeding	2 (3.0)
Additional plication after Endoscopy	13 (19.7)
Concomitant procedure	
Mitral valve repair	5 (7.6)
Tricuspid valve repair	2 (3.0)
Coronary bypass grafting	8 (12.1)
Patent foramen oval closure	16 (24.2)
Others	10 (15.1)
Early postoperative outcomes	
30-day mortality	2 (3.0)
Stroke	1 (1.5)
Myocardial infarction	1 (1.5)
Low cardiac output syndrome	1 (1.5)
Mid-term results	
Overall mortality	2 (3.0)
Re-operation	2 (3.0)

Data presented as mean ± SD or number (%). CPB, cardiopulmonary bypass; SD, standard deviation.

applied to the valve in 13 patients (e.g., *Figure 3*) after aortic valve evaluation using pressurized aortic root endoscopy. Out of these 8 patients who needed re-clamping, 2 patients had bleeding that could not stasis without arrested heart and the other 6 patients due to residual regurgitation that was underestimated during endoscopy. This residual aortic regurgitation was treated by resection of the non-coronary sinus in 1 patient (*Figure 4*), replacement of an aortic cusp using autologous pericardium in another patient, and additional plication was endorsed for the other 4 patients. After final weaning from CPB, intraoperative TOE control

revealed no aortic regurgitation was observed in 44 (66.7%) patients, and only trivial aortic regurgitation in 22 (33.3%) patients.

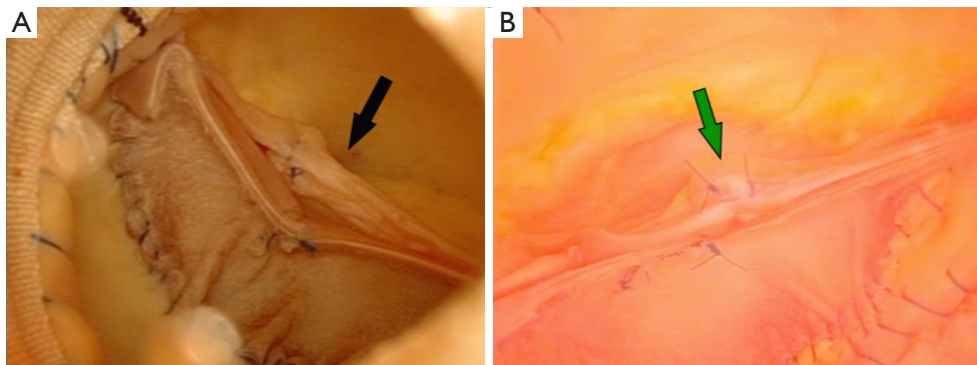
### Secondary study endpoints

Thirty-day mortality was 3% (n=2) due to stunning heart caused by severe left ventricular hypertrophy in one patient. The other patient experienced a massive cerebral bleeding after aortic valve re-implantation after acute type A aortic dissection. During follow-up (mean 28±10 months) no deaths occurred, but two patients showed recurrent aortic regurgitation. The first patient experienced a suture dehiscence between the autologous pericardial patches 7 months postoperatively. This patient already had a second cross-clamp during index surgery as mentioned above. During redo-surgery, the aortic valve was replaced by a mechanical substitute. The second patient, who showed a unicuspid aortic valve during index procedure and was initially treated by bicuspidalisation presented with acute cusp perforation 1 week postoperatively. This patient was successfully treated by replacement of the perforated cusp with tissue-engineered pericardium. Estimated overall freedom from reoperation (*Figure 5*) and cumulative survival (*Figure 6*) are illustrated with Kaplan-Meier curves. Finally, *Table 3* summarizes the echocardiographic assessment of the aortic regurgitation intraoperatively, at discharge as well as at the last follow-up.

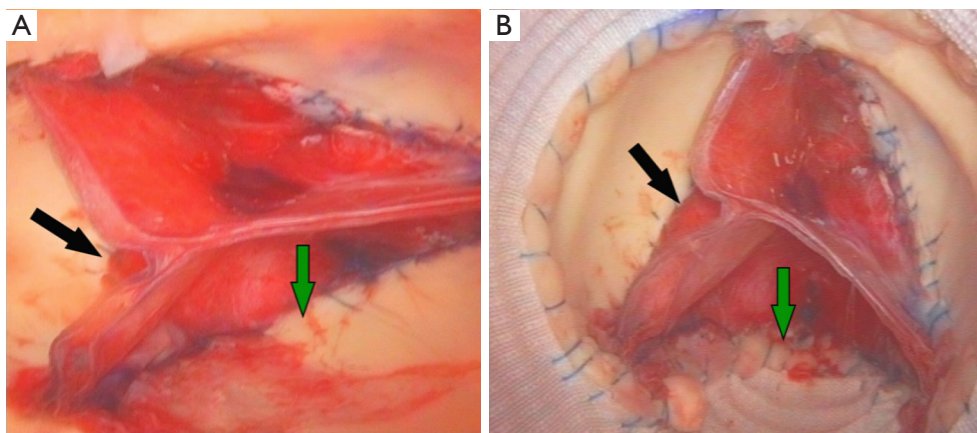
### Discussion

The main findings of this study are: (I) aortic valve endoscopy is a feasible tool, which can be easily applied to evaluate AVR before weaning of the CPB; (II) despite this helpful tool, unsuspected factors or under-estimated aortic regurgitation during endoscopic evaluation might cause second cross clamping; (III) early results of AVR with endoscopic guidance were good with a 30-day mortality of 3%; (IV) during follow-up, however, two patients needed reoperation due to severe aortic regurgitation, additional two patients have mild to moderate regurgitation and only none to trivial aortic regurgitation was observed for the rest of patients.

Currently, AVR or aortic sparing operations, such as aortic valve re-implantation [David's procedure (1), aortic root remodeling (2), various cusp repair techniques e.g., Ozaki's method (3)] are gaining increased interest. To test the competence of the repaired aortic valve, usually



**Figure 3** Intraoperative photo showing repaired aortic valve before and after additional repair after the use of endoscopy. (A) The black arrow refers to mal-coaptation of the cusps; (B) the coaptation line becomes optimal (green arrow) after additional plication.

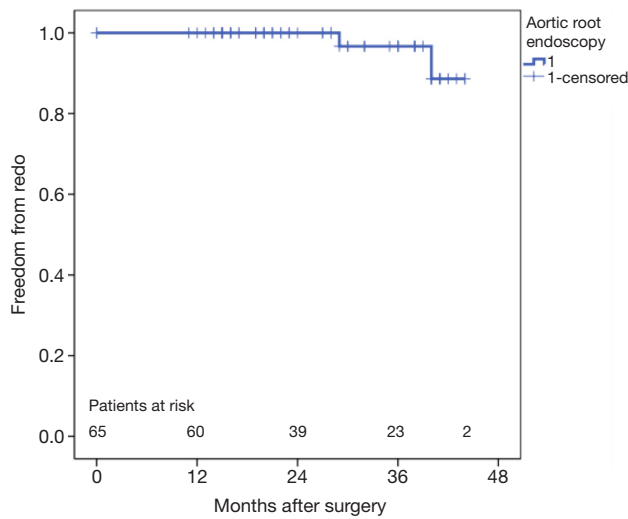


**Figure 4** Intraoperative photo showing constructed aortic valve before and after 2<sup>nd</sup> time clamping. (A) The black arrow refers to mal-coaptation of the new left coronary cusp due to redundancy of the non-coronary sinus (green arrow); (B) the coaptation line becomes perfect (black arrow) after replacement of the non-coronary sinus (green arrow).

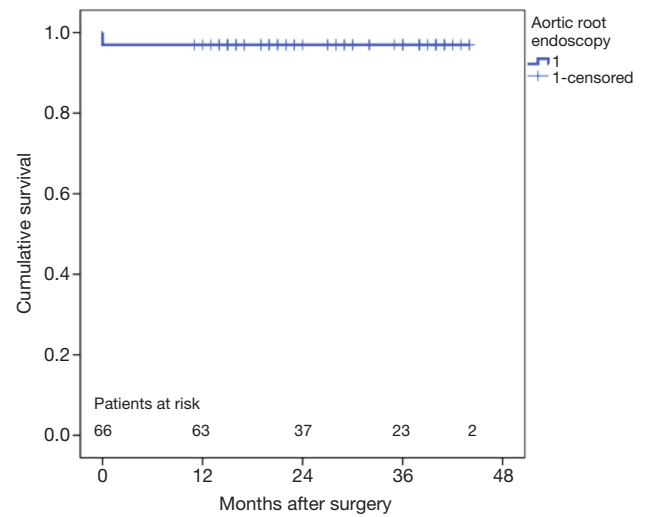
subjective test methods during cardioplegia-arrested heart in the non-beating situation are used, like saline flushing or excessive venting. Correct aortic valve function, however, depends not only on leaflet function, but also on other components, like the sinotubular junction, the aortoventricular junction as well as the aortic sinuses. The perfect combination of these components, during the dynamic situation of the cardiac cycle will lead to a competent aortic valve. This situation however, can be only achieved, when the heart is weaned from CPB. Then, TOE offers a detailed view of the repaired aortic valve, and competence can be evaluated, gradients can be measured and the coaptation height and length of the leaflets can be evaluated. Insofar, an objective method to directly evaluate the repaired aortic valve during cross clamping would be

advantageous. Therefore, an idea was suggested to visualize the aortic valve after repair in the diastolic position and under “physiologic” conditions, making the evaluation of the symmetry of the leaflets most similar to reality. Of course, our concept represents just an approximation towards physiological conditions, but it can be seen as a first step.

Early attempts to use an endoscope in the diagnosis or management of cardiac/vessel disease were discouraging due to visualization problems (4-6). These concepts disappeared with the introduction and possibility of open-heart surgery. Nowadays however, technology evolved and there is an increased demand for minimally invasive surgery. Therefore, new imaging options and modalities play a more and more important role in various surgical



**Figure 5** Kaplan-Meier curve showing estimated freedom from reoperation.



**Figure 6** Kaplan-Meier curve showing estimated cumulative survival.

**Table 3** Aortic regurgitation evaluation in echocardiography

Aortic regurgitation grad	Intraoperative TOE	Discharge TTE	Follow-up TTE
No AR	44	31	31
Trivial AR	22	29	30
Moderate AR	0	3	2
Severe AR	0	1	1

AR, aortic regurgitation; TOE/TTE, transoesophageal/trans thoracic echocardiography.

specialties. Duran first described the concept aortic valve endoscopy in 1991. He reported the use of a so-called “valvoscope” in three patients. In these patients, the method of aortic valve visualization was used to examine the proper leaflet length of left coronary neocusps. According to the visualized prolapse of this left coronary leaflet, Duran resected a few millimeters of the free edge to prevent potential coronary ischemia caused by the excessive leaflet material (7). Thereafter, Itoh and colleges rediscovered the concept of using an endoscope in 1997. They reported the successful and helpful use of intraoperative endoscopy in valve sparing operations to reduce the postoperative incidence of aortic regurgitation (8,9). They noted the potential indication of intraoperative endoscopy to evaluate AVR, as well as experimentally attempt to clarify the role of dilatation of the sinotubular junction as one cause of aortic regurgitation (10). Their results were encouraging and similar to our very primary

experience with root endoscopy (11).

The present study presents the early to mid-term results of 66 consecutive patients undergoing successful AVR in our center in which intraoperative aortic root endoscopy was applied. One of the main finding of the present study is, that intraoperative endoscopy during cardioplegia-arrested heart led to additional cusp plication in 13 patients and avoided second time cross-clamp and faster weaning from CPB in most [58] of the cases. However, 2<sup>nd</sup> cross-clamp was needed in 8 patients, 2 due to bleeding that could not be stasis without arrested heart, in the other 6 patients; a residual aortic valve regurgitation was defined with the TOE. This residual regurgitation needed additional correction and was treated by resection of the non-coronary sinus in 1 patient (Figure 4), replacement of an aortic cusp using autologous pericardium in another patient, and additional plication was endorsed for the other 4 patients. Of course, the pressurized plastic bag containing the cardioplegia is not able to

produce physiological conditions within the aortic root and moreover, obviously only the diastolic phase without any leaflet motion can be observed, in addition to the valve evaluation obtained by the endoscope are still quite subjective and could be underestimated from the surgeon himself due to the learning-curve of using endoscopy as well. Nevertheless, in our opinion, the particular advantages of this technique should be recognized: the technique itself is easy and fast to apply, very cost-effective, as all the components used were autoclavable and offers a “real-time” view on the pressurized aortic root after repair, which adds a certain amount of confidence to the surgeon. According to our “mid-term” results, the vast majority of patients present none to trace aortic regurgitation during follow-up, and only 2 patients had to be-operated due to residual/recurrent aortic regurgitation.

Due to our best knowledge today, there was only one study, which described the successful use of intraoperative endoscopic guidance in a small cohort of patients (n=17). In addition to our study, Ohtsubo and colleagues also inserted their endoscope directly after placing the aortic clamp and they evaluated the pathology prior to repair. They reported that 8 patients underwent aortic remodeling, 4 patients were treated by aortic valve re-implantation, and the remaining 5 patients received a valved-conduit. Three patients who underwent reimplantation procedure required late valve replacement for late progression of aortic regurgitation. They concluded that (I) aortic root endoscopy successfully reduced postoperative aortic regurgitation, (II) that root endoscopy might help to clarify the indications, but also limitations of valve-sparing root operations, and (III) that an endoscopically-judged minor prolapse might be a predictor for long-term results (9).

### Limitations

The present study was performed at a single tertiary care medical center and was retrospective. The generalization of our findings may not extend to all centers worldwide, as AVR is a complex procedure and comes with a “learning-curve”, which is also true for root endoscopy. Moreover, the application and interpretation of results, obtained by an endoscope are still quite subjective and were obtained under pseudo-“physiological” conditions and could be underestimated from the surgeon himself as seen in 6 patients of our series due to the learning-cure of using endoscopy as well. Further evaluation in larger cohorts is warranted.

### Conclusions

In conclusion, aortic root endoscopy is an easy to apply, and helpful tool to evaluate the repaired aortic valve before weaning from bypass. This technique might have the potential to lower the incidence of second cross clamping during AVR. Moreover, aortic root endoscopy might be also used for educational or training issues. To summarize, in our institution root endoscopy is routinely used, even in situations like acute aortic type A dissections, as we strongly believe in this helpful technique, as it is a further piece in the puzzle to get perfect results after AVR.

### Acknowledgements

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### Footnote

*Conflicts of Interest:* The authors have no conflicts of interest to declare.

*Ethical Statement:* The present study obtained IRB-approval (18-8199-BO) according to the Declaration of Helsinki.

*Disclaimer:* The autoclavable rigid video-scope (Endo-Eye®, Olympus, Tokyo, Japan) is CE approved.

### References

1. David TE, Feindel CM. An aortic valve-sparing operation for patients with aortic incompetence and aneurysm of the ascending aorta. *J Thorac Cardiovasc Surg* 1992;103:617-21; discussion 622.
2. Sarsam MA, Yacoub M. Remodeling of the aortic valve annulus. *J Thorac Cardiovasc Surg* 1993;105:435-8.
3. Ozaki S, Kawase I, Yamashita H, et al. A total of 404 cases of aortic valve reconstruction with glutaraldehyde-treated autologous pericardium. *J Thorac Cardiovasc Surg* 2014;147:301-6.
4. Rhea L, Walker IC, Cutler EC. The surgical treatment of mitral stenosis: experimental and clinical studies. *Arch Surg* 1924;9:689-90.
5. Allen DS, Graham EA. Intracardiac surgery—a new

- method. *Am Med Ass* 1922;79:1028.
6. Butterworth RF. A new operating cardioscope. *J Thorac Surg* 1951;22:319-22.
  7. Duran C, Kumar N, Gometza B, et al. Indications and limitations of aortic valve reconstruction. *Ann Thorac Surg* 1991;52:447-53; discussion 453-4.
  8. Itoh T, Ohtsubo S, Furukawa K, et al. Aortic root endoscopy in valve-sparing operations. *J Thorac Cardiovasc Surg* 1997;114:141-2.
  9. Ohtsubo S, Itoh T, Natsuaki M, et al. Successful valve-sparing in aortic root reconstruction under endoscopic guidance. *Eur J Cardiothorac Surg* 2000;17:420-5.
  10. Furukawa K, Ohteki H, Cao ZL, et al. Does dilatation of the sinotubular junction cause aortic regurgitation? *Ann Thorac Surg* 1999;68:949-53; discussion 953-4.
  11. Tsagakis K, Benedik J, El Khoury G, et al. Aortic valve repair: Intraoperative evaluation of valve geometry by angioscopy. *J Thorac Cardiovasc Surg* 2015;149:1666-8.

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