



## Minimally Invasive Aortic Root Surgery: Mid-Term Results in a 2-Year Follow-Up

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### Abstract

**Objectives:** Minimally Invasive Surgery (MIS) through Partial Upper Sternotomy (PUS) for aortic root surgery represents an alternative to the Full Median Sternotomy (FMS). PUS offers less operative trauma which improves the postoperative outcome. Nevertheless, the PUS requires a demanding surgical technique, with longer operation times, offering a reduced surgical field.

We analyzed the mid-term outcome of our patients who underwent either root replacement (Bentall) or aortic root sparing valve reconstruction (David) *via* PUS to evaluate the safety of this access.

**Methods:** Between 11/2011-04/2017, a total of 47 consecutive patients underwent aortic root surgery with aortic aneurysm and/or localized aortic dissection through Bentall or David operation through a J-shaped PUS (33 males, 14 females, and mean Age  $57.9 \pm 10.5$  years). Bentall operation was performed in 36 patients (77%), whereas 11 patients (23%) received a David procedure. Endpoints were procedure related complications, the 30-day and 2-year mortality, the need for re-do surgery and occurrence of MACCE in a 2-year follow-up. Postoperative patient's contentment analysis was performed using a questionnaire regarding the post-operative life quality, the satisfaction with the cosmetic result and the approach preference (PUS vs. FUS) for a potential following aortic surgery.

**Results:** In all patients a J-shaped sternotomy was applied. Respectively, mean operation time was  $287.3 \pm 72.6$  minutes, mean cardiopulmonary bypass (CPB) time  $174 \pm 54.8$  min, mean cross-clamp time  $133 \pm 33.1$  min. Re-thoracotomy due to postoperative bleeding was needed in six patients (13%). Superficial wound healing disturbance was observed in one patient (8%) and no deep sternal infection or sternum instability occurred. Hospitalization time was  $11.8 \pm 4.4$  days, mean ICU-stay  $1.9 \pm 1.3$  days with a ventilation-time of  $11.3 \pm 5.8$  h. During the first 30 postoperative days no MACCE occurred and the mortality rate was 0%. After 2 years the total rate of Mortality, occurrence of MACCE, and need for re-do surgery was as follow (6.3%, 4.2%, and 4.2%). 6 month after surgery 67% of the patients declared to have a better life quality and performance, 93% to be satisfied with the cosmetic result and 92% stated that they would prefer the PUS for a potential future aortic surgery.

**Conclusion:** Minimally invasive surgery of aortic root through partial upper sternotomy is a safe alternative to the full median sternotomy. Although it requires longer operative times, it offers-due to the diminished trauma-a reduced postoperative morbidity with a fast postoperative recovery and good postoperative outcome.

**Keywords:** Minimally invasive surgery; Aortic root surgery; Bentall operation; David operation; Partial upper sternotomy

### Abbreviations

MIS: Minimally Invasive Surgery; PUS: Partial Upper Sternotomy; FMS: Full Median Sternotomy; MACCE: Major Adverse Cardiac and Cerebrovascular Events; Bentall Procedure: Replacement of the Aortic Valve, Aortic Root, and Ascending Aorta, with Re-Implantation of the Coronary Arteries into the Graft; David Procedure: Valve-Sparing Aortic Root and Ascending Aorta Replacement, with Re-Implantation of the Coronary Arteries into the Graft; CPB: Cardiopulmonary Bypass; ICU: Intensive Care Unit; ECC: Extracorporeal Circulation; LV: Left Ventricle; LVOT: Left Ventricular Outflow Tract; SD: Standard Deviation; CAD: Coronary Artery Disease; CABG: Coronary Artery Bypass Grafting; BMI: Body Mass Index; NYHA: New York Heart Association; EC: Erythrocyte Concentrate; MI: Myocardial Infarction; AI: Aortic Valve Insufficiency

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## Introduction

Aortic root aneurysm and local dissection of the aortic root are rare vascular diseases, associated with a high mortality and morbidity [1,2]. Full Median Sternotomy (FMS) represents the standard conventional approach for the surgical treatment. Since the 1990s, Minimally Invasive Surgery (MIS) through a Partial Upper Sternotomy (PUS) has been used as an alternative access way in the surgical treatment of aortic valve and aortic diseases [3]. In the last years the pros and cons of this access were widely discussed [3-9]. Nowadays conventional aortic valve replacement is performed in ca. 10% as a MIS procedure *via* PUS, but only a few studies report a MIS approach for more demanding procedures on the aortic root [10-12], the ascending aorta [13] or the aortic arch [14]. In this work we present our clinical experience in treating aortic root aneurysm and localized aortic root dissection through minimally invasive PUS.

## Patients and Methods

We retrospectively reviewed 47 consecutive patients (33 male, and 14 female) who underwent surgical treatment of aortic root aneurysm or localized aortic root dissection through PUS between 11/2011 and 04/2017. In 36 patients (77%) a Bentall procedure was performed, whereas 11 patients (23%) received a valve sparing root replacement (David procedure). The mean age of patients was  $57.9 \pm 10.5$  years. The underlying pathology was in 45 patients (95.7%) an aortic root aneurysm and in 2 patients (4.2%) a localized aortic root dissection. 43 (91.4%) patients presented an aortic valve insufficiency. The mean EuroSCORE II was  $3.5 \pm 2.5\%$ . At admission 5 patients presented a coronary stenosis, without indication for surgical treatment. Patient demography and characteristics are shown in Table 1.

## Surgical Procedure

The preoperative aortic valve function was diagnosed *via* transthoracic echocardiography while the extension of a thoracic aortic ectasia or aneurysm was confirmed through a computed tomography scan. Routinely all patients received a preoperative coronary angiography in order to exclude a coronary artery disease. The operations were performed by five surgeons with variable technical experiences. The therapy decision in order to repair the aortic root using a valve-sparing technique (David) or a root replacement (Bentall) was taken intraoperatively, after direct visualization of the structure, geometry and calcification status of the valve leaflets. All procedures were performed in minimally invasive technique through PUS: An 8 cm skin incision was applied 4 cm caudal to the sternal notch. The sternum was partially opened *via* a J-shaped upper incision down to 3<sup>rd</sup> to 4<sup>th</sup> left intercostal space (Figure 1A). Four pericardial traction sutures were placed in order to expose the surgical field. After systemic heparinization direct aortic arch cannulation was performed using an 18 Fr arterial cannula. If this was not feasible due to a pathological enlargement of the proximal aortic arch, an open surgical cannulation of the right axillary artery was performed using a 17 Fr Femflex cannula (Figure 1B).

The venous cannulation of the right atrium was performed with a 28 Fr. venous line inserted via a substernal tunnel. After fixation of both cannulas with purse-string sutures, the Extracorporeal Circulation (ECC) was started. With gentle caudal traction on the venous line a caudal dislocation of the collapsed right atrium and an optimal exposure of the aortic root were created. An effective drainage if the Left Ventricle (LV) was reached by application of a flexible vent cannula via the left upper pulmonary vein into the LV.

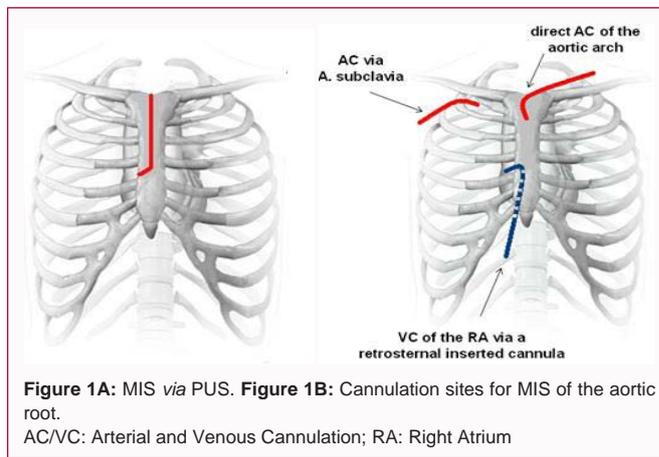


Table 1: Patients characteristics.

Characteristics	David	Bentall	Total
Number of Patients (n)	11	36	47
Mean age (years)	55.36 ± 11.0	60.05 ± 9.9	57.9 ± 10.5
Male (n, %)	8 (72.7%)	25 (69.4%)	33 (70.2%)
BMI (kg/m <sup>2</sup> )	25.8 ± 4.4	28.38 ± 4.1	27.3 ± 4.4
NYHA I	n=2 (18.1%)	n=8 (22.2%)	n=10 (21.2%)
NYHA II	n=5 (45.4%)	n=16 (44.4%)	n=21 (44.6%)
NYHA III	n=4 (36.3%)	n=10 (27.7%)	n=13 (27.6%)
EuroScore II (%)	3.72 ± 3.6	3.50 ± 2.10	3.5 ± 2.5
Ejection fraction (%)	51 ± 9.0	54 ± 9.1	53 ± 9.2
Coronary heart disease	n=3 (27.7%)	n=3 (8.3%)	n=5 (10.3%)
Aortic valve insufficiency	n=11 (100%)	n=32 (88.8%)	n=43 (91.4%)
Aortic valve stenosis	n=0 (0%)	n=13 (36.1%)	n=13 (27.6%)
Aortic aneurysm	n=10 (91%)	n=35 (97.2%)	n=45 (95.7%)
Aortic dissection	n=1 (9%)	n=2 (5.5%)	n=3 (4.2%)
Aortic diameter (mm)	55.27 ± 8.0	54.91 ± 5.0	55 ± 5.9

BMI: Body Mass Index; NYHA: New York Heart Association

The operation field was flooded with CO<sub>2</sub> in order to avoid air embolism during the open heart surgery.

Before cross clamping the aorta was dissected gently from the pulmonary artery in order to create an adequate clamping position. For aortic cross clamping the proximal part of the aortic arch was preferred, as close as possible to the aortic cannula, in order to facilitate an extended resection of the proximal diseased vessel. Cold blood cardioplegia (Buckberg) was applied into the ascending aorta if the aortic valve was competent. In patients with aortic insufficiency, the aorta was incised and cardioplegia was applied directly into the coronary ostia. Cardioplegia was repeated every 20 min or if cardiac electric activity was registered.

The primary goal of our treatment was a valve sparing root surgery in terms of a David-procedure (Figure 3). This was possible in 23% of our patients, who presented an enlarged aortic annulus, a tricuspid aortic valve, with no severe damage (degeneration or calcification) of the native aortic leaflets. In these patients the re-implantation technique of the native aortic valve as described by Tirone Esperidiao David [15,16] was applied: the aorta was transected at a level just above the coronary ostia. These were resected as small buttons and reattached later on to the aortic prosthesis. The aortic



Figure 2: Surgical view on the aortic root via PUS.

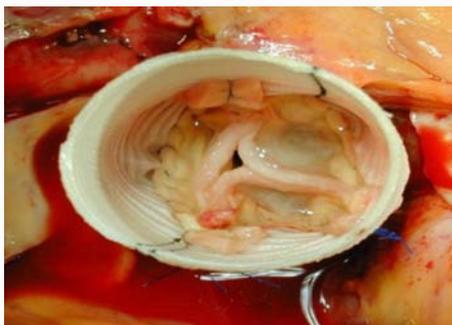


Figure 3: Valve sparing aortic root repair (David).

root was mobilized just below the nadir of aortic annulus and Teflon armed Ethibond 2-0 sutures were placed below the level of aortic valve, passing from LVOT to outside the aortic annulus. The aortic prosthesis was attached to the outside of the aortic annulus with the previously placed sutures. The native valve cusps were carefully positioned within the prosthesis ensuring the best coaptation and a proper movement. With a continuous suture technique the valve tissues were finally attached to the prosthesis and the coronary ostia were reimplanted with 6-0 Prolene running suture.

77% of the patients didn't fulfill the above mentioned valve criteria for a valve sparing procedure. In these patients a Bentall procedure using either a biological or mechanical valve conduit was used (Figure 4). Bentall procedure was applied as described by Hugh Bentall and Antony De Bono in 1968 [17]. The aorta was transected just above the aortic annulus, and the coronary ostia were resected as buttons. The degenerated native aortic cusps and the entire ascending aorta were resected. After prober sizing the valved aortic conduit was implanted using 12-15 previously placed sutures with pledgets passing from LVOT to outside the aortic annulus. Finally the coronary ostia were re-implanted at the base of the aortic conduit using 6-0 Prolene running suture.

The distal anastomosis of the aortic prosthesis to the native aortic arch was completed with Teflon reinforced 4-0 Prolene running suture. Before removing of the aortic clamp, carefully de-airing of the LV and the neo-aorta was performed by starting the mechanical lung ventilation, changing the position of the patient from Trendelenburg to anti-Trendelenburg and back to Trendelenburg accompanied by gently rhythmic compression the anterior wall of the LV using an atraumatic instrument.

After sufficient reperfusion, the LV was loaded under reduction of the ECC. Via concomitant transesophageal echocardiography an adequate valve function was verified and the presence of severe air bubbles was excluded. If bubbles persisted, de-airing was continued

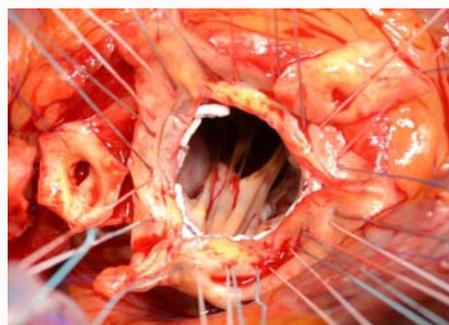


Figure 4: Aortic root replacement (Bentall).

Table 2: Intraoperative data.

Intraoperative data	David (n=11)	Bentall (n=36)	Total (n=47)
Operation time (min.)	287 ± 31	293 ± 79.5	287.3 ± 72.6
CPB time (min.)	180 ± 18	177 ± 61.0	174 ± 54.8
Aortic clamp time (min.)	149 ± 17	131 ± 35	133 ± 33.1
Reperfusion time (min.)	26.8 ± 7.4	29.9 ± 15.0	28.8 ± 13.8
Aortic cannulation	n=11 (100%)	n=31 (86.1%)	n=42 (89%)
Axillary cannulation	n=0 (0%)	n=5 (13.8%)	n=5 (11%)
Mechanical valve	n=0 (0%)	n=18 (50%)	n=18 (38%)
Biological valve	n=0 (0%)	n=18 (50%)	n=18 (38%)

CPB: Cardiopulmonary Bypass.

by re-activating the LV-vent or by inserting a needle on the highest point of the neo-ascending aorta. Weaning from ECC was performed only if the LV was free of air bubbles.

After removing the LV-vent and venous de-cannulation systemic protamine sulfate was administrated. At stabile hemodynamics the arterial line was removed. The right pleura was opened in order to avoid an unobserved pneumothorax and to assure better postoperative blood drainage. After insertion of two chest tubes—one in the pericardium and one in the right pleura—and placement of temporary pacing wires, the J-shape upper sternal incision was closed using 4 to 6 sternal wires. For postoperative surveillance the patients were transferred to the Intensive Care Unit (ICU).

### Documentation and data analysis

Patient's characteristics, demographic data, surgical data (operation type, times etc.) as well as early postoperative data (early procedure related complications, ICU-stay, postoperative morbidity and mortality) were collected retrospectively using the patient's clinical records. In Tables 1-3 continuous variables are presented as mean value ± Standard Deviation (SD) or as a median value.

After permission of the institutional ethics committee, the postoperative 30-day and 2-year follow up was assessed by contacting the patients or their physicians via telephonic interviews by a study nurse. The interviews focused on late procedure related complications, the 30-day and 2-year mortality, the need for re-do surgery or intervention and occurrence of MACCE in a 2-year follow up. These data are presented in Table 4 and 5.

For the qualitative analysis of the patient's contentment we designed a questionnaire which was send to all patients after 6 months post-surgery. Patients were asked about the postoperative quality of life (better, equal, or worse) compared with that just before the surgical procedure, about their satisfaction with the cosmetic

**Table 3:** Early postoperative data, in-hospital, and 30-day mortality.

postoperative data	David (n=11)	Bentall (n=36)	Total (n=47)
Ventilation time (min.)	11.5 ± 5.8	11.38 ± 5.6	11.3 ± 5.8
Bleeding (ml/1 <sup>st</sup> 24 h)	492 ± 225.1	526 ± 285.8	498.8 ± 284.9
Rethoracotomy	n=1 (9%)	n=5 (13.8%)	n=6 (12.7%)
Blood products EC	2.9 ± 3.1	3.1 ± 3.2	3.12 ± 3.9
ICU Stay (Days)	2.5 ± 1.7	1.8 ± 1.1	1.9 ± 1.3
Hospital Stay (Days)	12.6 ± 5.1	11.6 ± 4.1	11.8 ± 4.4
Sepsis	n=0 (0%)	n=0 (0%)	n=0 (0%)
Pneumonia	n=0 (0%)	n=0 (0%)	n=0 (0%)
Superficial wound healing disturbance	n=0 (0%)	n=1 (2.7%)	n=1 (2%)
Deep sternal infection	n=0 (0%)	n=0 (0%)	n=0 (0%)
Sternal instability	n=0 (0%)	n=0 (0%)	n=0 (0%)
30-day mortality	n=0 (0%)	n=0 (0%)	n=0 (0%)

EC: Erythrocyte Concentrate; ICU: Intensive Care Unit

**Table 4:** Mid-term follow up (Mortality, MACCE, re-operation).

Procedure	6 months		12 months		24 months		Total after 24 months (n, %)
	David	Bentall	David	Bentall	David	Bentall	
Mortality (n, %)	0	0	0	1 (2.7)	1 (9.0)	1 (2.7)	3 (6.3)
MACCE (n, %)	1 (9.0) (Stroke)	1 (2.7) (MI)	0	0	0	0	2 (4.2)
Re-operation (n, %)	0	0	0	1 (2.7)	0	1 (2.7)	2 (4.2)

MACCE: Major Adverse Cardiac and Cerebrovascular Events; MI: Myocardial Infarction

result and if they would prefer the PUS-approach again, in a potential second operation.

## Results

### Surgical procedures and operative variables

Data of different operative times and variables as well as operative variables of Bentall vs. David procedures are presented in Table 2. Arterial cannulation for ECC was performed as direct aortic cannulation in 89% and via the axillary artery 11% of the patients. The total operation time was 292 ± 71 min. Total means cardiopulmonary bypass and aortic cross clamp time was 177 ± 54 min and 135 ± 32 min. The total mean reperfusion time was 28 ± 13.8 min. In the Bentall-group 50% of the patients received a mechanical aortic conduit and 50% a biological conduit. There was no conversion to full sternotomy in all 47 patients.

### Early post-operative outcome

Data of the early postoperative course are presented in Table 3. All patients were transferred under anesthesia and mechanical ventilation to the ICU. Total mean ventilation time was 11.3 ± 5 min. The amount of bleeding through thoracic drainages in the first 24 h was 498 ± 284 ml. The mean number of transferred erythrocyte concentrate was 3 ± 3.9 units. Chest re-exploration was indicated by bleeding amount more than 1000 ml/ in the first 24 h, and these was necessary in 6 Patients. Mean duration of ICU stay was 1.9 ± 1.3 days, the total hospital stay 11.8 ± 4.4 days. During the hospitalization period the post-operative survival was 100%. During this period no incidence of sepsis or pneumonia was mentioned. Only one superficial (pre-sternal) wound infection but no deep sternal infection occurred.

### Mid-term follow up

The 30 day survival was 100%. A mid-term follow has been completed in 94% of the patients. In Table 4 data about mortality,

re-do surgery, and incidence of MACCE in the mid-term follow up are presented at three post-operative time points. After two year the rate of mortality was 6.3% (n=3), the need for re-do surgery rate 4.2% (n=2) and the incidence of MACCE 4.2% (n=2). The causes of mortality and re-do surgery are presented in Table 5. Two patients have been re-operated with Re-Bentall. The first patient developed one year after the initial operation a tear in the aortic prosthesis with significant aortic valve insufficiency; furthermore, he had a progression of his Coronary Artery Disease (CAD). In the second operation he received a Re-Bentall plus Coronary Artery Bypass Grafting (CABG). The second patient had to be re-operated two years later due to prosthetic endocarditis.

Regarding the patient's contentment 67% reported a better quality and performance, 24% felt no difference and 9% of the patients reported worse quality and performance of their life in comparison to preoperative status. 93% of the patients reported to be satisfied with the cosmetic result of the operation via the small incision. 92% stated that they would prefer the same PUS for a potential future aortic surgical approach.

## Discussion

Over the last years minimally invasive surgery with partial sternotomy has been used as an alternative access to the standard full sternotomy for aortic valve surgery [4]. There are different types of partial sternotomy [5-7]. The mostly common type is a J-shaped PUS. In this access the upper part of sternum is incised down to the 3<sup>rd</sup> or 4<sup>th</sup> right intercostal space. The benefit of this MIS approach for aortic valve surgery has been proved in numerous practical studies compared with the standard and usual access with FMS [8-11]. It reduces the surgical trauma, which leads to less postoperative pain, and an enhanced recovery of the respiratory function. The preserved lower part of sternum, as an intact part of the native chest

**Table 5:** Cause of mortality and type of reoperation.

Mortality n=3 (6.3%)	Cause
two patients	Multi organ failure after reoperation
one patient	Unknown cause
Reoperation n=2 (4.2%)	Type
1 <sup>st</sup> patient	CABG + Re-Bentall (due to a tear in the valve prosthesis with AI)
2 <sup>nd</sup> patient	Re-Bentall (due to endocarditis)

CABG: Coronary Artery Bypass Graft; AI: Aortic Valve Insufficiency

architecture, increases sternal stability and reduces the risk of sternal wound infection. Furthermore it leads to shorter hospitalization time, a faster recovery and rehabilitation. On the other hand, patients benefit from the better cosmetic results.

Since aortic root replacement using the Bentall technique and valve sparing aortic root surgery using the David procedure are complex operations, which request a good overview over the mediastinum, FMS has been used as standard access. Recently PUS has been reported to be used as an alternative access in these complex procedures [12-14] but still not routinely performed.

In 2011 the strategy in our department has been changed to be more oriented to minimally invasive surgery techniques. We started to use a J-shaped PUS as standard access for almost all isolated aortic valve procedures. That enriched our experience with this approach and we expanded the indication of PUS for elective complex aortic root and ascending aortic surgery.

As mentioned above there are numerous studies which describe the effectiveness and results of PUS in isolated aortic valve surgery. Nevertheless, less is known about the results and safety of this approach in aortic root and ascending aortic surgery. Hillebrand et al. [2] investigated 33 patients who underwent aortic root replacement with Bentall procedure through a J-shaped PUS (Group A) compared with similar procedure in 25 patients through FMS (Group B) and proved the safety of PUS in complex aortic surgery. The results were comparable to the conventional approach with FMS. According to Shrestha et al., [11] valve sparing aortic root replacement using the David technique in 26 patients *via* J-shaped PUS was feasible and safe when compared with same procedure in FMS. This was confirmed by Mikus, et al. [1] in a study of 53 patients who received a Bentall procedure using PUS. Finally Wachter et al. [18] proved the safety of valve-sparing aortic root replacement with David procedure *via* PUS, when he compared the two approaches – PUS (117 Patients *vs.* FMS (75 Patients).

In our cohort the 30 day mortality was 0%, similar to the early post-operative results of Shrestha et al. [11] and Mikus et al. [1] According to Wachter et al. [18] the 30 day mortality was 0.9% in the minimally invasive group *vs.* 2.7% in the conventional group.

Regarding the peri-operative data, our procedure times were comparable with those of the other studies. Nevertheless, our patients had a higher re-thoracotomy rate due to bleeding (n=6, 12.7%) when compared to Hillebrand et al. [2] (6.06%), Shrestha et al. [11] (3.2%) and Wachter et al. [18] (5.6%). We followed a radical re-thoracotomy policy taking a 'second look' if the thorax drainage volume  $\geq$  1000 ml. Since no active focal bleeding source but a general coagulation disorder was found in all six re-thoracotomy patients, it could be summarized retrospectively, that the re-thoracotomy rate could be lower, if we played on time. Nevertheless, in our conception the

smaller pericardial incision and the limited pericardial drainage *via* the PUS are less permissive for post-operative pericardial effusions, which may lead to tamponade. That is why we fenestrated the pericardium (right sided), opened the right pleura at the end of the procedure and followed an early re-thoracotomy policy in order to prevent this complication. Although the re-sternotomy rate was high, no sternal instabilities or deep sternal infection occurred.

The in-hospital and ICU stay periods were  $11.8 \pm 4.4$  and  $1.9 \pm 1.3$  respectively shorter in our cohort, when compared to Hillebrand et al. [2] ( $13.36 \pm 9.27$  and  $2.45 \pm 3.43$ ) and Wachter et al. [18] ( $12.4 \pm 7.7$  and  $2.6 \pm 4.9$ ). A reason for this multifactorial finding may be the absence of serious complications like postoperative acute heart failure, pneumonia, sepsis and deep sternal infections or sternal instability in our group.

The decisive parameters for a good mid- or long-term outcome are the survival, incidence of MACCE, re-do surgery (for the same, not primary sufficient treated pathology) and not to be forgotten—the patients postoperative contentment with the surgical result. Latest represents a very individual parameter, that includes a summary of factors like postoperative pain, the recovery duration, the cosmetic result and, last but not least, the functional result.

Wachter et al. [18] investigated the outcome of patients with a valve sparing root surgery in a 5 year follow-up. The authors found a superior 5 year survival in the PUS-group when compared to the FMS-group (99% *vs.* 86%,  $p=0.037$ ), which could not be explained only by the less invasive approach but also by the circumstance that the patients in the PUS-group were younger and had less comorbidities. In our study we had a 2 year follow-up. Our patients demonstrated a mortality rate of 2.1% after one year, which increased to 6.3% after two years. Though, our data were comparable with previous published data for conventional aortic root surgery: 2.02% one year mortality rate following conventional Bentall [19], respectively a 11% mid-term mortality rate for valve sparing aortic root replacement reported by Bori Bata et al. [20] ( $5.3 \pm 3$  years mean follow-up).

The cardiac re-operation rate in our patients was 4.2% after two years. These data are similar with those reported by other groups: Coselli et al. reported a re-operation rate of 5% in 83 patients who underwent a valve sparing aortic root replacement (3.5 years median follow-up), whereas Sareyyupoglu et al. [21] presented a higher re-operation rate of 12% in 84 patients who underwent a valve sparing aortic root replacement at a mean of 3.4 years after surgery.

For Bentall procedures Sabol et al. [22] reported a re-operation rate of 13.4%. In our study two patients (4.2%) had to be re-operated, both underwent a Bentall procedure. Cause for re-do surgery was a prosthetic endocarditis in one patient, respectively a tear in the valve prosthesis resulting in valve insufficiency in the second one.

The innovation in our retrospective analysis, when compared to the literature, represents the estimation of the postoperative quality of life and the role of the cosmetic result on patient satisfaction with the surgical procedure. Since the aortic enlargement often goes on without typical symptoms—unless there is a serious valve insufficiency or stenosis—we were surprised by the reported superior life quality and performance post-surgery in 67% of the patients. One of the reasons for this may be the good early recovery due to the partially preserved chest architecture, which subjectively encourages the patient to an early mobilization.

The high satisfaction with the cosmetic result (93%) as well as the

statement to prefer The PUS-approach for future aortic surgeries has to be seen a subjective way: Since the patients had no previous cardiac surgery the only term of comparison was the direct comparison with the larger scar seen by FMS-patients during the same hospitalization period.

Nevertheless we are convinced that the diminished operative trauma, the less postoperative pain and fast postoperative recovery are important factors in reducing the total duration of hospitalization and the subsequently post-hospital rehabilitation. This could reduce the cost of medical care and simultaneously increase the patient's satisfaction.

## Conclusion

The previous published results of other study groups could prove the feasibility and safety of operating combined aortic root and ascending aortic pathology *via* PUS. The minimal invasive upper partial sternotomy offers similar or superior short and mid-term results, when compared to FMS. Our data enhance these results, and show that the patient's acceptance for this innovative MIS approach is high. Using a standard PUS for ascending aortic surgery may require longer operative times, operative skills and experience and a longer learning curve when compared to FMS, but on the other hand offers less surgical trauma, less sternal instability and a better cosmetic results, which could be an important factor for a lot of patients.

## Limitation

We present a retrospective, non-randomized study, without a propensity matched control group (PUS *vs.* FMS). The patient's cohort is small, but it is one of the largest with a completed mid-term follow up including MACCE, re-do surgery and mortality following complex aortic root surgery *via* a minimal invasive approach. The novum of this study is the evaluation of the patient's contentment following aortic root surgery *via* PUS. However studies with larger patient numbers are still required, in order to prove these findings.

## Central Message

Minimally invasive surgery of aortic root through partial upper sternotomy is a safe alternative to the full median sternotomy. It offers a good postoperative outcome.

## Perspective Statement

In our Study Minimally Invasive (MIS) J-shaped sternotomy had a comparable operative and short postoperative Outcomes to the same operation with Full Median Sternotomy (FMS) in literature. Furthermore the J-shaped sternotomy offers similar or superior mid-term results, when compared to FMS. Our data enhance these results, and show that the patient's acceptance for this innovative MIS approach is high.

## References

- Mikus E, Micari A, Calvi S, Salomone M, Panzavolta M, Paris M, et al. Mini-Bentall: An Interesting Approach for Selected Patients. *Innovations (Phila)*. 2017;12(1):41-5.
- Hillebrand J, Alshakaki M, Martens S, Scherer M. Minimally Invasive Aortic Root Replacement with Valved Conduits through Partial Upper Sternotomy. *Thorac Cardiovasc Surg*. 2018;66(4):295-300.
- Bakir I, Casselman FP, Wellens F, Jeanmart H, De Geest R, Degrieck I, et al. Minimally invasive versus standard approach aortic valve replacement. *Ann Thorac Surg* 2006;81(5):1599-604.
- Murtuza B, Pepper JR, Stanbridge RD, Jones C, Rao C, Darzi A, et al. Minimal access aortic valve replacement: is it worth it? *Ann Thorac Surg*. 2008;85(3):1121-31.
- Scarci M, Young C, Fallouh H. Is ministernotomy superior to conventional approach for aortic valve replacement? *Interact CardioVasc Thorac Surg*. 2009;9(2):314-7.
- Brown ML, McKellar SH, Sundt TM, Schaff HV. Ministernotomy versus conventional sternotomy for aortic valve replacement: a systematic review and meta-analysis. *J Thorac Cardiovasc Surg*. 2009;137(3):670-9.e5.
- Skripochnik E, Michler RE, Hentschel V, Neragi-Miandoab S. The Efficacy and Outcome of Ministernotomy Compared to Those of Standard Sternotomy for Aortic Valve Replacement. *ISRN Minim. Invasive Surg*. 2014;2014:254084.
- Lim JY, Deo SV, Altarabsheh SE, Jung SH, Erwin PJ, Markowitz AH, et al. Conventional versus minimally invasive aortic valve replacement: pooled analysis of propensity-matched data. *J Card Surg*. 2015; 30(2):125-34.
- Filip G, Bryndza MA, Konstany-Kalandyk J, Piatek J, Wegrzyn P, Ceranowicz P, et al. Ministernotomy or sternotomy in isolated aortic valve replacement? Early results. *Kardiochir Torakochirurgia Pol*. 2018;15(4):213-8.
- Totaro P, Carlini S, Pozzi M, Pagani F, Zattera G, D'Armini AM, et al. Minimally invasive approach for complex cardiac surgery procedures. *Ann Thorac Surg*. 2009;88(2):462-7.
- Shrestha M, Krueger H, Umminger J, Koigeldiyev N, Beckmann E, Haverich A, et al. Minimally invasive valve sparing aortic root replacement (David procedure) is safe. *Ann Cardiothorac Surg*. 2015;4(2):148-53.
- Monsefi N, Risteski P, Miskovic A, Moritz A, Zierer A. Midterm Results of a Minimally Invasive Approach in David Procedure. *Thorac Cardiovasc Surg*. 2018;66(4):301-6.
- Perrotta S, Lentini S. Ministernotomy approach for surgery of the aortic root and ascending aorta. *Interact Cardio Vasc Thorac Surg*. 2009;9(5):849-58.
- Ahmad A, Risteski P, Papadopoulos N, Radwan M, Moritz A, Zierer A. Minimally invasive approach for aortic arch surgery employing the frozen elephant trunk technique. *Eur J Cardiothorac Surg*. 2016;50(1):140-4.
- 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(4):617-21.
- David TE, David CM, Manlhiot C, Colman J, Crean AM, Bradley T. Outcomes of Aortic Valve-Sparing Operations in Marfan Syndrome. *J Am Coll Cardiol*. 2015;66(13):1445-53.
- Bentall H, De Bono A. A technique for complete replacement of the ascending aorta. *Thorax*. 1968;23(4):338-9.
- Wachter K, Franke UF, Yadav R, Nagib R, Ursulescu A, Ahad S, et al. Feasibility and clinical outcome after minimally invasive valve-sparing aortic root replacement. 2017;24(3):377-83.
- Mookhoek A, Korteland NM, Arabkhani B, Di Centa I, Lansac E, Bekkers JA, et al. Bentall Procedure: A Systematic Review and Meta-Analysis. 2016;101(5):1684-9.
- Bori Bata AK, D'Ostrevy N, Pereira B, Geoffroy E, Dauphin N, Eljezi V, et al. Valve-sparing aortic root replacement-midterm outcomes and quality of life. *Cardiovasc Diagn Ther*. 2017;7(6):572-80.
- Sareyyupoglu B, Suri RM, Schaff HV, Dearani JA, Daly RC, Orszulak TA, et al. Survival and reoperation risk following bicuspid aortic valve-sparing root replacement. *J Heart Valve Dis*. 2009;18(1):1-8.
- Sabol F, Kolesar A, Jankajova M, Luczy J, Holoubek D, Artemiou P, et al. Aortic valve-sparing operation versus Bentall and mechanical aortic valve replacement--midterm results. *Bratisl Lek Listy*. 2014;115(5):292-9.