Endoscopic Port Access™ left ventricle outflow tract resection and atrioventricular valve surgery

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Abstract: The continuous evolution in robotic-, endoscopic- and trans-catheter cardiac interventions resulted in innovative techniques that simultaneously address left ventricular outflow tract obstruction (LVOTO) and concomitant atrioventricular valve (AVV) pathology in the context of hypertrophic obstructive cardiomyopathy (HOCM). We present our brief report of 13 consecutive HOCM patients with concomitant AVV disease, who underwent endoscopic left ventricular septal myomectomy (LVSM) and AVV surgery by Endoscopic Port Access™ Surgery (EPAS) between March 1st 2010 and October 31st 2015. Our EPAS technique in the context of HOCM utilizes peripheral cardiopulmonary bypass, endo-aortic balloon occlusion and a 4-cm right antero-lateral thoracic working port. Access to the LVOTO is obtained by detaching the anterior mitral valve (MV) leaflet from the annulus. Controlled sharp LVSM is then performed from the aortic leaflet base to the papillary muscles. Subsequent routine AVV surgery is performed using long shafted instruments. There were no sternotomy conversions, LVSM complications or 30-day mortalities. The mean length of hospitalization was 17.7±18.1 days. Long-term clinical and echocardiographic analysis of 645.7 patient-months (n=13, 100.0% complete) identified two late mortalities, which were not procedure-, HOCM- or AVV-related. All patients (n=13, 100.0%), including the late mortalities, had significant improvement in their quality of life, a 100% long-term freedom from re-intervention and no residual peak instantaneous LVOTO gradients more than 15 mmHg. This brief report emphasises that simultaneous LVSM and concomitant AVV surgery by EPAS can safely be performed in experienced centres with favourable long-term outcomes.

Keywords: Minimally invasive port access surgery; mitral and tricuspid valve diseases (MV and TV diseases); hypertrophic obstructive cardiomyopathy (HOCM); outcome

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Introduction

Adult hypertrophic obstructive cardiomyopathy (HOCM) is as an autosomal dominant cardiac sarcomere protein gene abnormality associated with an annual 1–2% sudden cardiac death risk (1) and is defined as unexplained left ventricular (LV) thickness greater than 15 mm in 1 or more LV segments resulting in LV outflow tract obstruction (LVOTO), LV-diastolic dysfunction and conduction abnormalities. Systolic anterior motion (SAM) and regurgitation of the mitral valve (MV) may occur due to concomitant anterior MV-leaflet elongation and anterior papillary muscle displacement towards the LV outflow tract (LVOT). Degenerative-, infective- and rheumatic atrioventricular valve (AVV) disease may also be present as independent pathology in the context of HOCM and LVOTO. Left ventricle septal myomectomy (LVSM) with or without concomitant AVV surgery is conventionally performed either by isolated trans-aortic, trans-atrial, trans-ventricular or combined trans-aortic valve and left atrial access (2-8) through midline sternotomy. The progressive paradigm shift towards endoscopic (9), robotic (10) and trans-catheter cardiac interventions (11,12) resulted in

Table 1 Pre-operative patient characteristics (n=13)

Variable	Values
Age, mean ± SD (years)	57.3±14.5
Female, N (%)	5 (38.5)
Mean body mass index, mean ± SD (range) (kg/m^2)	27.6±5.1 (22.5–42.2)
Comorbidities present, N (%)	
Hypertension	9 (69.2)
Hypercholesterolemia	5 (38.5)
Type I diabetes mellitus	1 (7.7)
Previous Cardiac Surgery	2 (15.4)
Chronic obstructive pulmonary disease	2 (15.4)
Atrial fibrillation	7 (53.8)
Renal dysfunction	2 (15.4)
Pulmonary Hypertension	8 (61.5)
Mean systolic pulmonary artery pressure, mean ± SD (range) (mmHg)	36.5.9±14.4 (25.0–80.0)
Critical pre-operative state, N (%)	1 (7.7)
Mean EuroSCORE II, mean ± SD (range)	4.2±5.4 (1.0–17.8)
Mean left ventricular function, mean ± SD (range) (%)	62.1±7.8 (55.0–77.0)
Mean left ventricular outflow tract gradient, mean ± SD (range) (mmHg)	74.8±42.5 (15.0–173.0)
Mean interventricular septum diameter, mean ± SD (range) (mm)	19.5±4.5 (15.0–28.0)
Mitral valve regurgitation, N (%)	13 (100.0)
Grade II	2 (15.4)
Grade III	5 (38.5)
Grade IV	6 (46.2)
Tricuspid valve regurgitation, N (%)	9 (69.2)
Grade I	6 (46.2)
Grade II	1 (7.7)
Grade III	2 (15.4)
New York Heart Association functional status, N (%)	
II	4 (30.8)
III	9 (69.2)

Table 2 Isolated and combined surgical indications (n=13)

Surgical indications	N (%)
Mitral valve dysfunction	13 (100.0)
Systolic anterior motion (SAM)	12 (92.3)
Endocarditis	1 (7.7)
Myxomatous degenerative disease	2 (15.4)
Rheumatic valve disease	1 (7.7)
Tricuspid valve dysfunction	3 (23.1)
Patent foramen ovale	3 (23.1)
Atrial fibrillation	2 (15.4)

innovative techniques to simultaneously address LVOTO and AVV pathology. This brief report of 13 consecutive HOCM patients with concomitant AVV pathology, presents the perioperative and long-term clinical and echocardiographic outcomes of LVSM and AVV surgery by Endoscopic Port Access Surgery™ (EPAS), operated by our current surgical team between March 1st 2010 and October 31st 2015.

Patient selection and work-up

EPAS is the routine procedure for isolated AVV disease at our institution (13) and no pre-operative contra-indications prohibit our endoscopic approach. We reported our experience in difficult access extreme obese patients (14), congenital chest wall deformities (15), redo-cardiac surgery (16) and redo-EPAS after previous EPAS (17). The relevant preoperative HOCM patient characteristics and surgical indications are outlined in *Tables 1,2* respectively. Presenting symptoms included angina, syncope and dyspnoea in 6 (46.2%), 4 (30.8%) and 9 (69.2%) patients respectively. The pre-operative peak LVOT gradient of 173 mmHg measured in one patient was confirmed by trans-oesophageal echocardiography (TEE) and catheterization. Two (15.4%) patients had previous cardiac operations, which included a minimally invasive direct coronary artery bypass grafting (104.3 months prior to current HOCM presentation) and conventional sternotomy aortic valve replacement with Morrow-procedure (1.3 months prior current HOCM presentation) at another institution.

Pre-operative preparation

Pre-operative aorta-iliac-femoral-axis (AIFA) evaluation is

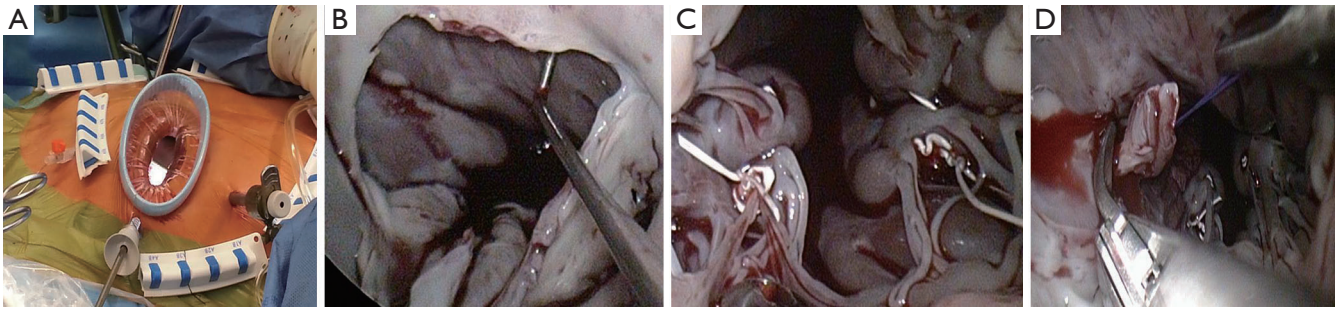

Figure 1 Routine EPAS setup (A) is followed by left ventricular outflow tract (LVOT) access. The anterior mitral valve (MV)-leaflet segments A1–A3 are detached from its anterior annular attachment (B). Both papillary muscles are plicated away from the LVOT (C). Left ventricle septal myomectomy is subsequently performed by controlled sharp muscle resection that extent from the aortic valve towards the left ventricle apex up to the base of the papillary muscles (D). EPAS, Endoscopic Port Access Surgery.

Table 3 Procedures performed, cardiopulmonary bypass- and endo-balloon occlusion times (n=13)

Procedures performed	Values
Mitral valve repair, N (%)	7 (53.8)
Ring implantation	7 (53.8)
Leaflet patch reconstruction (anterior/posterior)	7 (53.8)
Leaflet resection	2 (15.4)
Cleft closure	2 (15.4)
Papillary muscle plication/transfer	7 (53.8)
Secondary chordae release	1 (7.7)
Neo-chordae implantation	6 (46.2)
Edge-to-edge repair	1 (7.7)
Mitral valve replacement, N (%)	6 (46.2)
Tricuspid valve repair (ring implantation), N (%)	1 (7.7)
Permanent pacemaker implantation, N (%)	1 (7.7)
Patent foramen ovale closure, N (%)	3 (23.1)
Left atrial appendage exclusion, N (%)	3 (23.1)
Cryo-ablation, N (%)	2 (15.4)
Elective hybrid percutaneous coronary intervention, N (%)	1 (7.7)
Cardiopulmonary bypass time, mean ± SD (range) (minutes)	202.2±65.5 (133.0–314.0)
Endo-balloon occlusion time, mean ± SD (range) (minutes)	140.2±49.3 (76.0–220.0)

routinely performed in all patients either during coronary catheterization or by magnetic resonance angiography. We do not routinely perform computerized tomography in redo-surgery and perform no special investigation to evaluate the presence of lung adhesions. Routine cardiac surgical workup is followed by an elaborate informed consent process in which the various options are discussed and a final treatment strategy elected.

Equipment preference card

All LVSM and isolated AVV procedures in the context of HOCM are performed by EPAS using special long shafted instruments without additional special equipment. A bovine pericardial patch is used to augment the anterior MV leaflet if required.

Procedure

Our routine EPAS technique (18) is modified in the context of HOCM and concomitant AVV pathology. However, the standard EPAS operative setup remains unchanged (*Figure 1A*). Peripheral cardiopulmonary bypass (CPB) is established by TEE-guided cannulation of the right internal jugular vein (16–18 Fr, Optisite™, Edwards Lifesciences, Irvine, California, USA), right femoral vein (22–25 Fr, Quickdraw™, Edwards Lifesciences, Irvine, California, USA) and right femoral artery cannulation (21 or 23 Fr, Endoreturn™, Edwards Lifesciences, Irvine, California, USA). An endo-aortic balloon (IntraClude™, Edwards Lifesciences, Irvine, California, USA) is utilised for aortic occlusion and delivery of cold antegrade crystalloid cardioplegia. Routine and complex MV and tricuspid valve (TV) surgery, as outlined in *Table 3*, are performed with long shafted instruments through a 4th intercostal, antero-lateral thoracic working port. Access to the LVOT

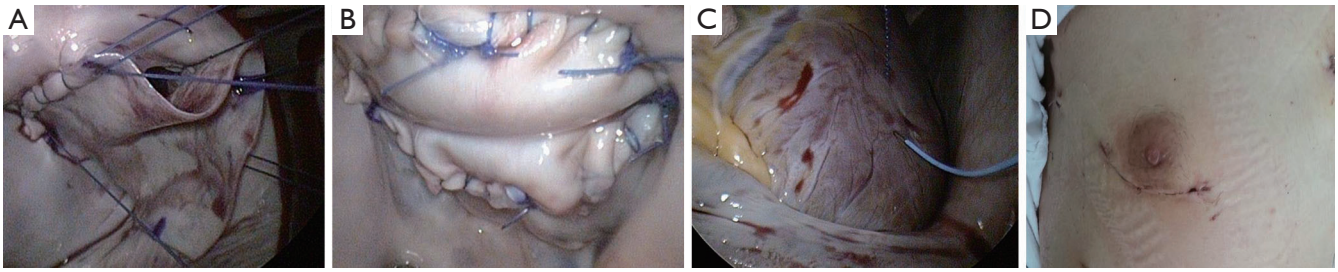

Figure 2 Re-attachment of the anterior MV-leaflet to the annulus is performed with the incorporation of an oversized pericardial patch (A) and the concluded mitral valve repair reviewed (B). A temporary pacemaker wire is attached to the diaphragmatic surface of the left ventricle (C) and routine post-operative recovery initiated (D). MV, mitral valve;

is obtained by detaching the anterior MV-leaflet from the annulus (*Figure 1B*), which is followed by routine plication of both papillary muscles away from the LVOT (*Figure 1C*). Controlled sharp LV-septal muscle resection is performed from the base of the aortic valve to the papillary muscles (*Figure 1D*), of which the excision depth is guided by pre-operative LV-septal diameter by TEE measurements. LV-septum perforation and extensive resection in conduction regions are avoided. In cases of MV-repair, an oversized bovine pericardium patch is incorporated into the annular re-attachment (*Figure 2A*,*B*). Significant SAM was present in 12 (92.3%) patients, of which successful MV repair was achieved in 7 (53.8%). MV-replacements were reserved for rheumatic, advanced myxomatous or high-risk valves for short-term repair failure. For TV surgery through a right atriotomy, the superior and inferior vena cave are snared. Cryo-ablation is performed with an argon-gas surgical ablation system (Medtronic, Minneapolis, USA), the base of the left atrial appendage oversewn in patients with atrial fibrillation or previous stroke and patent foramen ovale also routinely closed. Post-procedural de-airing is ensured by left atrial and aortic balloon venting catheters, continuous flooding of the operative field with CO_2 and TEE surveillance for residual air in the left ventricle. Temporary epicardial (*Figure 2C*) or trans-jugular ventricular pacing wires are routinely placed.

Team members

All patients are presented at a specialised multi-disciplinary team meeting, which consist of cardiac surgical, cardiology, anaesthetic, radiology, allied medical, trainee and administrative staff members. Operative procedures are conducted within a specialised team context that consist of a TEE trained anaesthetist (19), two minimally invasive cardiac surgeons and a trainee, operative nurses and a perfusionist experienced in EPAS perfusion (20) procedures. Post-operative intensive care is coordinated by a team of full-time on-site cardiac intensivists, which is followed by a structured and individualised in-hospital multi-disciplinary rehabilitation program. Finally, continuation of care ascertained by the referring physician as part of patient centred service delivery.

Post-operative management

Cardio-respiratory support, sedation and analgesia are administered as indicated in intensive care and a structured in-hospital rehabilitation program (*Figure 2D*) initiated as soon as possible. All patients undergo pre-discharge trans-thoracic echocardiographic evaluation for satisfactory operative result confirmation. Infective endocarditis is treated with appropriate antibiotics for 6 weeks under the supervision of an infective endocarditis team and long-term anti-coagulation regimes initiated and stabilized in-hospital in cases of mechanical prosthetic implantation or chronic atrial fibrillation. All patients are reviewed within 6 weeks post-discharge, after which continuation of care is ascertained by the referring cardiologist and family physician.

Outcomes

There were no sternotomy conversions, complications in establishing vascular or LVOT access, LV-septum perforations or 30-day mortalities. One (7.7%) patient presented with active staphylococcal MV-endocarditis, a peak instantaneous LVOT gradient of 88.0 mmHg and interventricular septum diameter (IVSD) of 22 mm. The patient underwent extensive anterior and posterior MV-

Table 4 In-hospital morbidities (n=13)

Morbidity	N (%)
Revisions	2 (15.4)
Residual valve dysfunction	1 (7.7)
Bleeding	1 (7.7)
Stroke	1 (7.7)
Acute renal dysfunction requiring dialysis	2 (15.4)
Respiratory morbidity	
Residual pleural collections requiring drainage	1 (7.7)
Hospital acquired pneumonia	1 (7.7)
Post-surgery rhythm abnormalities	
Post-operative permanent pacemaker implantation	2 (15.4)
New onset atrial fibrillation	2 (15.4)

Table 5 Echocardiographic and clinical outcomes (n=13)

Outcomes	Values
Echocardiographic follow-up (mean 36.6±30.1 months)	
Mean left ventricle ejection fraction, mean ± SD (%)	54.9±8.4
Residual mitral valve regurgitation equal to or less than grade I, N (%)	11 (84.6)
Residual tricuspid valve regurgitation more than grade II, N (%)	2 (15.4)
Peak left ventricle outflow tract gradient <15 mmHg, N (%)	13 (100.0)
Mean interventricular septal diameter, mean ± SD (mm)	14.2±4.9
Mean systolic pulmonary artery pressure, mean ± SD (mmHg)	34.5±13.0
Clinical follow-up (mean 49.7±30.0 months)	
New York Heart Association functional status, N (%)	
Class I	9 (69.2)
Class II	4 (30.8)
New onset atrial fibrillation, N (%)	1 (7.7)

leaflet resection, debridement, autologous annular patch and leaflet xenograft pericardial patch reconstruction in addition to LVOT resection. Revisions for bleeding (n=1, 7.7%) and residual MV-dysfunction post-repair (n=1, 7.7%) were performed through the same incisions without residual complications. One (7.7%) patient developed an ischemic stroke on the 10th post-operative day due to a MV-mechanical prosthesis thrombosis that resolved with conservative therapy. The patient was eventually discharged after 72 days in hospital. There were no wound infections or persistent air leaks and the mean length of hospitalization was 17.7±18.1 days (range, 7.0–72.0 days). Other in-hospital morbidities are outlined in *Table 4*. Post-operative dialysis was required in 2 (15.4%) patients, of whom 1 (7.7%) had severe renal impairment pre-operatively. Both patients were subjected to cardiopulmonary perfusion times of 133.0 minutes. Post-discharge echocardiographic and clinical data (645.7 patient-months) are described in *Table 5* and were obtained by reviewing the latest consultation records (n=13, 100.0% complete), of which 12 (92.3%) patients had follow-up periods longer than 2 years. Clinical follow-up (mean, 49.7±30.0 months) for survival identified two late mortalities at 40.1 (fatal stroke, age 82.6 years) and 85.0 post-operative months (ischemic colitis, age 76.5 years) respectively. There were no procedure-, HOCM-, AVV-related late mortalities or re-interventions. All patients (n=13, 100.0%), including the late mortalities, were classified as New York Heart Association (NYHA) I or II during their latest clinical review. Echocardiographic follow-up (mean, 36.6±30.1 months) identified no residual or recurrent peak instantaneous LVOT gradients more than 15 mmHg. Asymptomatic chordal SAM was diagnosed in 1 (7.7%) patient with a mean gradient of 11 mmHg (40.1 months post-operative).

Tips, tricks and pitfalls

LVOT resection with or without AVV surgery is most commonly performed through conventional mid-line sternotomy and is not recommended as part of the initial EPAS skills acquisition in upcoming centres. For experienced EPAS operators, this approach provides direct and targeted access to the LVOT, the majority of the interventricular septum, the MV and TV. Plication of the papillary muscles away from the LVOT reduces the risk of residual valvular and chordal SAM and is considered an essential step for a successful LVOT gradient reduction outcome. Annular detachment of the anterior MV should be wide and extend from segment A1 to A3. Careful suture retraction of the detached anterior MV-leaflet facilitates

unobstructed endoscopic access to the LVOT. LVSM depth is determined by pre-operative TEE diameter measurements and perforation avoided by careful *en-bloc* sharp resection from the base of the aortic valve to the papillar muscles. The incorporation of an oversized bovine pericardial patch into the anterior MV-leaflet ensures that the coaptation line is pushed posteriorly, which decreases the risk of residual valvular SAM. TEE should confirm an adequate and uncomplicated LVSM and AVV procedure.

Conclusions

This small series of a very limited patient population reflects the outcomes of the current surgical team of a single centre with extensive EPAS experience. Simultaneous LVSM and AVV surgery by EPAS is safe, effective and allow for durable LVOT gradient reduction, SAM- and AVV-surgery outcomes. Our series achieved a 100% long-term freedom from re-intervention and improved quality of life in all patients with no significant new or recurrent echocardiographic AVV pathology. EPAS offers the potential benefits associated with minimally invasive cardiac surgery and is an attractive alternative to conventional approaches for HOCM and concomitant AVV disease.

Acknowledgements

None.

Footnote

Conflicts of Interest: Dr. F Van Praet and Dr. F Casselman serve on the Edwards Lifesciences Medical Advisory Board for minimally invasive cardiac surgery. Dr. J van der Merwe has no conflicts of interest to declare. This study was presented at EACTS, Vienna, 2017.

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