RESEARCH ARTICLE

Totally Endoscopic Uniportal Surgical Aortic Valve Replacement via Transcervical Approach: How to Do It

Authors

Fraser Sutherland, MD[1], Nawwar Al-Attar, MD[1], Radoslaw Smoczynski, MD[2], Piotr Suwalski, MD[2]

Affiliations

[1] Department of Cardiac Surgery, Golden Jubilee National Hospital, Glasgow, United Kingdom.

[2] Department of Cardiac Surgery, Central Clinical Hospital of the Ministry of Interior, Centre of Postgraduate Medical Education, Warsaw, Poland.

Correspondence:

Fraser Sutherland, MD

Email: fraser.sutherland@gjnh.scot.nhs.uk

Abstract

The number of aortic valve interventions continues to increase. Although transcatheter aortic valve replacement (TAVR) was a milestone in the field, it is quite uncertain whether this technique will completely supplant surgical aortic valve replacement (SAVR) due to its recognized shortcomings and access limitations. However, TAVR can be considered in short-term the competitor to SAVR and therefore, there is a pressing clinical need for a less invasive SAVR procedure, capable of delivering superior outcomes when compared with TAVR, without the level of invasiveness of current approaches to SAVR.

Different totally endoscopic aortic valve replacement approaches have been described. Nevertheless, we believe that these can be improved and facilitated by cutting-edge technology such as CoreVista® Retractor and CoreVista® Monitor in the surgical field and the feasibility of a single, unique port access centred upon a small transcervical incision to perform the entire procedure. This paper explores the current state of the art and presents detailed how-to-do-it steps for implementing Totally Endoscopic Uniportal SAVR based upon the Transcervical Approach.

Keywords: CoreVista; endoscopic; SAVR; transcervical; valve replacement.

1. Introduction

The number of patients requiring aortic valve intervention worldwide is rapidly increasing, driven by increased life expectancy, patient expectations and better diagnosis.[1] Since 1960, surgical aortic valve replacement (SAVR) has been traditionally considered the 'gold standard treatment'.[2]

However, over the last 10 years, transcatheter aortic valve replacement (TAVR) has rapidly emerged as a minimally invasive alternative treatment, having similar outcomes to SAVR regarding survival and quality of life.[3]

Although TAVR revolutionized the landscape of structural heart disease as it is a minimally invasive technique, it is unlikely that TAVR will completely supplant SAVR for the treatment of severe aortic stenosis. The latter has excellent short- and long-term outcomes.[4]

In addition, increased life expectancy will likely drive a requirement for extended valve durability which may not be adequately achieved with TAVR alone. TAVR has some well known long-term common complications such as permanent pacemaker implantation due to atrioventricular conduction disturbances [5] and increased rates of valve thrombosis. [6]

Consequently, surgery will continue to be a real treatment option for many patients. Nonetheless, if TAVR is to be the comparator to SAVR in the short term, there is a pressing need for surgeons to make the SAVR procedure very much less invasive and thus attractive to patients.

In order to reach this goal, surgery on the aortic valve and related structures has progressed with the use of minimally invasive approaches, achieving better clinical outcomes than the standard sternotomy.[7,8]

2. State of the Art

In an effort to perform a less invasive SAVR procedure, cardiac surgeons have upgraded their surgical skills so that they are able to operate on-screen, employing fine minimally invasive surgical (MIS) instruments. Every step of the standard SAVR procedure has been critically appraised.

Examples of how the minimally invasive techniques have evolved in cardiac surgery include the endoscopic mitral and tricuspid valve procedure, which has become a first line treatment in many hospitals around the world. Although aortic valve replacement is usually performed through a hemi-sternotomy or through a right anterior mini-thoracotomy, totally endoscopic approaches to the aortic valve have been adopted by a few investigators lately.

Pitsis A et al reported a totally endoscopic aortic valve replacement procedure through multiple small incisions. [9] A small right parasternal working incision in the 2nd intercostal space (ICS), a port for the endoscope in the same ICS laterally, anterior to the right anterior axillary line, a separate stab wound incision in the 1st ICS for the Chitwood aortic cross clamp, a stab wound incision in the 5th ICS anterior axillary line to insert a right superior pulmonary vein vent and finally a transverse aortotomy port proximal to the fat body of the aorta to excise the aortic valve, debride and wash the annulus. This technique has shown to decrease intensive care stay times amongst other obvious advantages.

Similarly, Vola M et al. reported a proof of concept in cadavers then first clinical cases using five-trocar settings; two working ports, a camera trocar and two trocars for management of pulmonary vent and carbon dioxide insufflation line. [10]

All procedures were technically successful although one conversion to second space mini-thoracotomy was required after repositioning of the valve became necessary. Nevertheless, it proved that totally endoscopic aortic valve replacement is technically feasible.

Use of the da Vinci robot for surgical aortic valve replacement through endoscopic approach has also been described by Balkhy and others. [11-13] These authors have provided proof of concept for robot assisted excision of non-calcified aortic valve leaflets and closure of the aortotomy. These specific tasks are very easily done using conventional MIS instruments. In fact, closing the longitudinal aortotomy in uniportal, transcervical SAVR could not be simpler.

Interestingly however, the ability to lock the robotic instrument wrists could be useful for exposure of the valve (seen in the video attached to the Balkhy paper) and debridement of calcified aortic valve leaflets using long MIS instruments, which can require considerable dexterity, may possibly be improved with robot assistance.

Nonetheless, the current da Vinci platform seems too large and cumbersome for these activities especially via Uniportal access. Newer platforms coming to the market may be more useful.

The development of sutureless aortic valves is also known to facilitate minimally invasive aortic valve replacement, avoiding the placement and tying of sutures, reducing cross-clamp and cardiopulmonary bypass duration, maintaining satisfactory hemodynamic outcomes with low paravalvular leak and pacemaker implantation rates.[14] Suturing a valve is still possible in minimally invasive surgery and may be enhanced with modern suture placing and knot tying devices and aids.

3. Rationale

Although significant progress has been made regarding the invasiveness of the procedure and clinical outcomes, we truly believe that the current techniques can be significantly improved in terms of invasiveness, access to the aortic valve and surgeon's comfort.

This paper will describe the individual steps required to perform Totally Endoscopic SAVR via the Uniportal Transcervical approach in detail, bringing into the field patented cutting-edge technology like CoreVista® Retractor and CoreVista® Monitor (CardioPrecision, Glasgow, United Kingdom).

The main advantage of the proposed approach is that the transcervical access is almost pain free compared to right thoracotomy, which is typically considered painful. Furthermore, we consider that the access to the aortic valve from the side, via multiple ports, is not the ideal approach while performing SAVR.

There are currently no hard data pertaining to the learning curve for the set of surgical procedures that can be performed through the new transcervical approach. An aptitude for manipulating endoscopic instruments and an appreciation of the constraints of uniportal access are obviously essential. However, endoscopic learning is significantly improved by preservation of visual motor mapping that is afforded by the CoreVista® Monitor position within the user's immediate task space, just above the incision. Therefore, it is anticipated that interested surgeons should be able to pick up the necessary skills very quickly.

Previous reported techniques included a small right anterior thoracotomy incision and multiple small incisions or ports with or without the robot. We believe that the procedure should be performed through a unique single 'working port', approaching the valve in the midline from above using the transcervical neck incision and using CoreVista® Retractor and CoreVista® Monitor. This technology has been successfully used before as a novel less invasive approach for surgical aortic valve replacement by Dapunt.[15]

This novel approach brings a monitor into the surgical field, which is mounted in the line of sight of the surgeon, improving the eye-hand coordination, ease of learning and comfortable position during the surgical procedure. The following account represents the current state of the art for totally endoscopic uniportal SAVR.

4. How to Do It

A high definition (HD) surgical monitor is brought into the surgical field and positioned immediately above the incision for close alignment of visual and motor axes and therefore optimal hand-eye coordination. The high definition monitor is in the line of sight of the surgeon.

Studies of endoscopic skill learning have consistently shown that the visual display should be placed directly ahead of the operator to preserve visual-motor mapping. [16]

The monitor is sheathed in a sterile drape with clear window after the screen protective cover has been peeled off.

Clarity and brightness are remarkable and the monitor is 'plug and play' with factory pre-sets so no adjustment is necessary. It is recommended NOT to wear loupes for this procedure but to operate substantially on-screen.

A transcervical incision or working port is made two fingers' breadth (3-4 cm) above the sternal notch. Stay sutures are placed on the lower skin edge and either held up by an assistant or attached to surgical clips.

Figure 1. CoreVista® Retractor and Accessories.

The surgeon should aim for the sternal notch in the dissection and divide the interclavicular ligament. It is recommended to carefully mobilise under each sternoclavicular joint and also along the anterior border of sternocleidomastoid muscles on each side to improve exposure.

Dissection proceeds under the sternum using a 4mm 30-degree endoscope with lens facing upwards and a long tip diathermy, predominately operating on-screen. The surgeon should stay close to sternum and ultimately detach the sternohyoid muscles from their sternal attachments. The scope is held by a surgical assistant who should preferably stand to the right of the surgeon. The HD monitor is designed for wide angle viewing so the surgical assistant is easily able to observe the screen. Continuous smoke evacuation is necessary for optimal viewing.

The single use CoreVista® Retractor is introduced under the sternum, hooked onto the lifting arm and connected with the CoreVista® Light Guide (Figure 1). The CoreVista® Lifting Arm is then elevated by a theatre technician by winding handle of the CoreVista® Actuator. The foregoing creates an ergonomic 'uniportal' access to the chest.

The CoreVista® Retractor has a unique patented design that permits cardiothoracic surgery to be performed through the short transverse incision in the neck. Light settings designed to illuminate different zones of the operative field in sequence with the typical steps of a cardiothoracic operation performed through this uniportal access in the neck.

The CoreVista® Retractor is central to the totally endoscopic, uniportal approach. The sequenced lighting allows the operator to switch easily between on-screen viewing and direct viewing through the incision when the scope is removed for cleaning or particular steps of the operation, such as parachuting of valve prosthesis into the aortic root.

Nonetheless, surgery is substantially performed with the aid of a 4mm 30-degree endoscope whose image is relayed in high definition to the screen in front of the surgeon. Identification of the lower border of brachiocephalic vein is the first major landmark that needs to be encountered. This vessel passes transversely across the field immediately posterior to the sternohyoid muscles and is generally located within *circa* 5 cm inside of the incision. The surgeon should begin to expose arterial structures from the lower border of the vein and expect to proceed in a generally caudal and posterior direction to the ascending aorta.

The next key step in the operation is identifying and opening of the pericardium. The pericardial reflection is then dissected laterally off the aorta to expose the superior portion of ascending aorta.

All of the above steps are preferably performed using the diathermy and importantly, prior to the administration of heparin in order to maintain a dry field.

Remote cannulation for CPB is required.

The principles of minimalist cannulation originally described by Hugo van Hermann are employed.

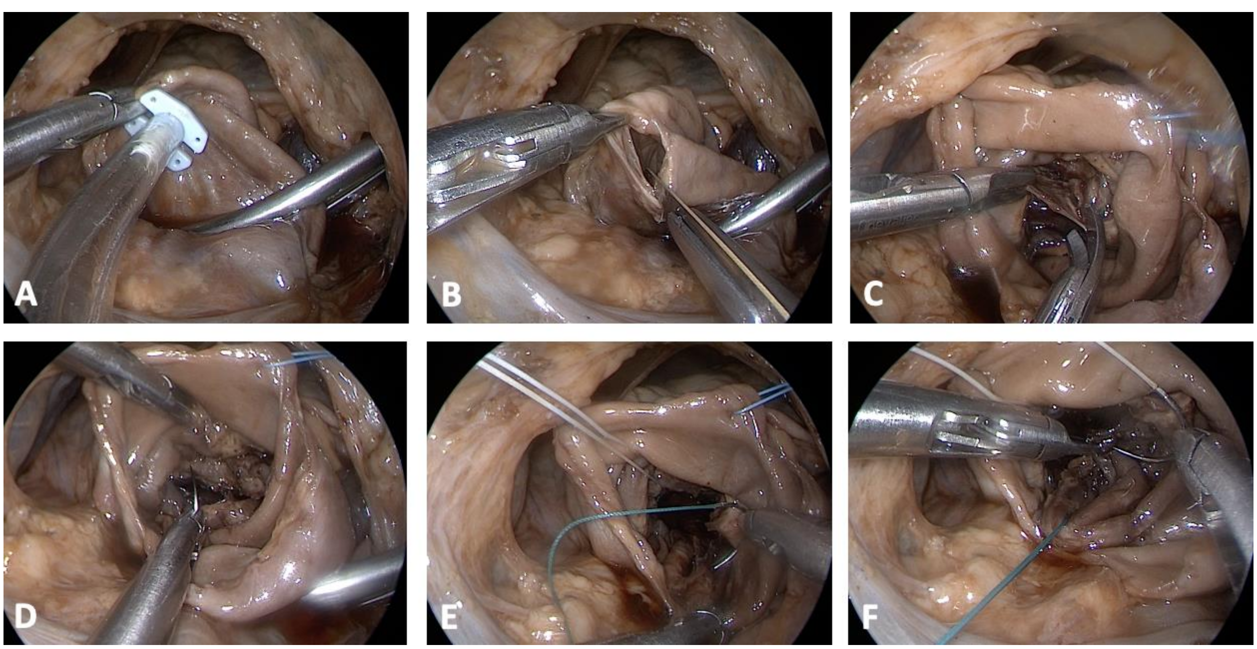

Figure 2. Key steps of the operation observed on the CoreVista® Monitor: Application of cross clamp and delivery of cardioplegia (A), longitudinal aortotomy (B), excision of native valve leaflets (C), placement of first guiding suture (D), placement of retraction suture in commissure (E), placement of second guiding suture (F)

A long femoral venous cannula is advanced from the groin and its position in the superior vena cava (SVC) confirmed by digital palpation. Femoral arterial cannulation was employed in the original description [15] but as surgeons become increasingly familiar with cannulation of subclavian arteries, the left common carotid artery and/or the brachiocephalic trunk, all of which techniques are easily taught, it is expected that retrograde perfusion of the aorta will progressively be abandoned; access to the aortic arch is also possible through the transcervical incision.

A transthoracic clamp is introduced from the right side (Figure 1). The clamp enters the chest through a stab incision roughly 6 cm from lateral sternal edge in the 1st intercostal space.

The clamp is passed anterior to the SVC and oriented with the greater curvature of its jaws facing the surgeon and the lower jaw thus allowed to drop behind the aorta as the clamp is opened. Clamping of the aorta differs from the technique employed in minimally invasive mitral cases as the jaws must be placed more distally on the aorta and the point of entry of the clamp into the chest is more medial and higher on the chest. The clamp may be secured to the lifting arm with a Nylon tape for optimal positioning.

Cardioplegia is instilled directly into ascending aorta through a long cannula that has been pre-shaped into a gentle curve by the surgeon (Figure 2A). Transesophageal echocardiography is used to quantify valve competency and monitor ventricular distension during cardioplegia. Intraoperative CO_2 insufflation by the field flooding technique reduces the risk of postoperative neurocognitive dysfunction.[17]

Once diastolic arrest is achieved the cardioplegia cannula is removed and the opening in the aorta extended in a longitudinal direction (Figure 2B).

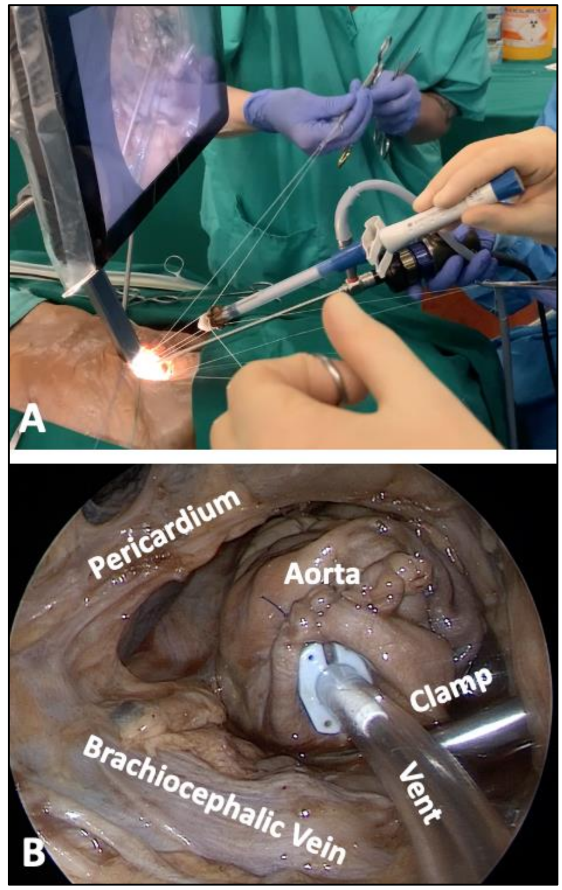

Figure 3. (A) Implantation of sutureless aortic valve prosthesis. **(B)** Venting of aorta after closure of aortotomy just prior to removal of cross clamp.

The incision should be curved slightly to the left along the natural lateral curvature of the aorta towards the commissure between left coronary and right coronary sinuses.

Stay sutures are placed on each side of the aortotomy and led out of the wound onto clips which can either be left hanging under their own weight or attached to the drapes. The 4mm 30-degree scope is positioned just inside the incision with the 30-degree lens facing downwards

Additional doses of cardioplegia can be delivered into right and left coronary ostia using a right angled cannula. Attention is turned to excision of the calcified native valve leaflets (Figure 2C). It is recommended to use a combination of sharp dissection with a knife and to gently peel calcium away from the native annulus curved with MIS scissors, similar in technique to an endarterectomy.

The scope can be advanced for close inspection of structures and then withdrawn to facilitate actual surgical manoeuvring.

When the scope is deep inside the wound it is important to keep it between the target and the surgical instrument. With practice these manoeuvres can be easily choreographed by surgeon and assistant for a fast, efficient operation. In the future it is possible that a robot may be helpful in facilitating these manoeuvres.

When sutureless valve is employed, the guiding sutures are most easily placed at the nadir of the three sinuses as follows.

For RCA sinus, the needle is mounted and passed in a hooked fashion from below (Figure 2D). For NCA sinus, a stay suture is first placed through the commissure between LCA and NCA sinuses (Figure 2E) and retracted to expose the nadir of the NCA sinus whereupon the guiding suture is most easily passed with the needle mounted forehand and passed from sinus to ventricular side (Figure 2F). For LCA sinus, the guiding suture is placed in the nadir of the sinus with the needle mounted forehand and again the suture is passed from the sinus to the ventricular side.

The annulus is sized and an appropriate valve selected, prepared and advanced through the transcervical incision (Figure 3A). A sutureless or rapid deployment valve is preferred.

The scope and HD monitor allow perfect visualisation of the valve prosthesis during and after deployment (Figure 4). The longitudinal aortotomy is easily closed and vent replaced for de-airing just prior to clamp removal (Figure 3B). A chest drain can either be led out of the neck incision or exited

Figure 4. Post implantation dilation of sutureless valve.

through the cross clamp access site on the right chest.

As with all surgical procedures, meticulous attention to haemostasis is required during closure. Any large veins that are encountered should be ligated.

Careful attention to skin closure along with strict adherence to aesthetic principles is recommended. Local anaesthetic is instilled into the wound and the patient recovery is shortened as postoperative analgesic requirement through this access is minimal.

5. Advantages of Totally Endoscopic Transcervical Approach to SAVR

The theoretical advantages anticipated from uniportal, totally endoscopic, uniportal transcervical approach over conventional minimally invasive SAVR are those common to all minimalist procedures i.e. less pain, less blood loss, shorter hospital stay and faster recovery. These advantages have notably and consistently been realised in minimalist surgical mitral valve repair; [18] indeed, with the widely utilised peri-areolar incision developed by Poffo and associates [19] patients experience almost no pain and a near perfect cosmetic result.

Just as the peri-areolar incision was 'borrowed' from plastic surgery, where it was used for enhancing mammoplasty by reason of its excellent functional and cosmetic results, [20] the transcervical incision has been 'borrowed' from general and thoracic surgery because of its excellent functional results by way of facilitating day case surgery [21] and almost imperceptible cosmesis when proper aesthetic principles of access are applied. [22]

The anticipated advantages of this procedure over TAVR draw from the proven benefits of SAVR over TAVR and include divergence in outcomes at five years discussed in the introductory paragraphs along with all of the advantages that follow from complete excision of native valve at the time of surgery. For SAVR in general, there has been a substantial decline in operative mortality to less than 1% in many series.[23]

Furthermore, data from the OBSERVANT study shows that SAVR is associated with much lower mortality and major adverse cardiac and cerebrovascular events rates than transfemoral TAVR at five years post intervention.[24] There is a strong case favouring surgery if patients can be persuaded to forego the perceived short term benefits of a percutaneous intervention.

As with the totally endoscopic mitral surgical procedure, the on-screen approach envisaged in totally endoscopic transcervical approach to the aortic valve is more comfortable for the surgeon as it entails operating from a seated position without loupes and the on-screen display can provide a much improved visualisation of the valve both during surgery and at the end of the operation when very close inspection of the implanted prosthesis is possible.

Cost is also a consideration as the price of the valve prosthesis is much higher for TAVR than SAVR ($32,500 versus $5,000) and the index procedure cost is thus $20,000 higher for TAVR than SAVR. Currently, high procedure costs for TAVR are offset but differences in length of ICU stay and overall length of stay which are much longer for SAVR than TAVR (differences 2.8 days and 6.3 days, respectively) and by the need for more rehabilitation after SAVR.[25] However, once surgeons have mastered the technique of totally endoscopic SAVR by the uniportal transcervical approach, the more rapid patient recovery anticipated should eliminate differences in ICU and hospital stay and reduce the need for rehabilitation making SAVR the more cost effective procedure.

6. Conclusion

We believe that invasiveness is at the crux of the patient's decision on mode of aortic valve intervention. Long-term outcomes are likely to be superior with SAVR over TAVR but TAVR's short term advantage over SAVR fundamentally resides in its level of invasiveness.

Although different techniques have emerged that make minimally invasive SAVR less invasive than conventional full sternotomy SAVR there is a pressing need for cardiac surgeons to adopt a totally endoscopic approach to SAVR that makes it very much less invasive in order to remain competitive.

We believe that the Totally Endoscopic, Uniportal Technique described herein, centred on a single, transcervical working port and making use of new, cutting-edge technology like CoreVista® Retractor and

CoreVista® Monitor is the future of SAVR operation due to the **decreased invasiveness** of the transcervical approach and **improved operative accuracy** associated with the mounted surgical monitor located within the surgical field directly above the incision which maximises hand-eye coordination in the surgeon’s immediate task space.

7. Declared conflict of interest

Dr Fraser Sutherland is a Director and Chief Medical Officer for CardioPrecision Ltd.

Authors Professor Al-Attar, Dr Smoczynski and Professor Suwalski declare that they have no conflicts of interest.

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