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Minimally Invasive Surgical Aortic Valve Replacement: An Overview of Recent Advances

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ABSTRACT

Aortic valve replacement (AVR) is the only definitive treatment for severe aortic stenosis. Options for valve replacement include surgical AVR (SAVR) and percutaneous transcatheter AVR. Although transcatheter AVR has recently been shown to be the optimal approach for high-risk patients, SAVR is the gold standard for patients with low and intermediate surgical risk. Advances in technique and innovations in rapid-deployment and sutureless valves have facilitated the development of a third alternative. Accumulating evidence suggests that minimally invasive SAVR can be performed as safely as conventional SAVR, and perhaps with less morbidity, allowing patients a quicker return to their productive lives. The following discussion outlines the surgical technique, patient selection and advances in valve design.

RÉSUMÉ

Le remplacement valvulaire aortique (RVA) est le seul traitement définitif existant de la sténose aortique grave. Ce remplacement peut se faire selon différentes modalités, dont le RVA chirurgical (RVAC) et le RVA par transcathéter percutané. S'il a été montré récemment que le RVA par transcathéter est l'approche optimale pour les patients à haut risque, le RVAC n'en demeure pas moins le traitement de référence pour les patients dont le risque chirurgical est faible ou modéré. Les avancées techniques et les innovations en matière de valves à déploiement rapide sans suture ont permis la mise au point d'une troisième option. De plus en plus de données probantes indiquent qu'un RVAC minimalement invasif peut être effectué de façon aussi sûre que le RVAC classique, et que cette nouvelle modalité pourrait entraîner une morbidité moindre, permettant aux patients de reprendre plus rapidement le cours normal de leur vie. Dans le présent article, nous décrivons la technique chirurgicale, les critères de sélection des patients et les avancées récentes en matière de conception de valves.

Aortic valve replacement (AVR) is the only curative intervention for severe aortic stenosis and conventional surgical AVR (SAVR) is the most common approach with well documented long-term outcomes.[1] Nevertheless, it is an invasive open-heart procedure that requires a sternotomy with its associated morbidity. Transcatheter AVR offers a percutaneous alternative, which has shown encouraging results in elderly, high-risk populations.[1] In moderate- and low-risk groups, it has not shown superiority and its long-term durability is yet to be determined. For an expanded version of this report with a more extensive reference list, see the Supplementary Material.

First described by Cosgrove and Sabik in 1996, minimally invasive AVR (mis-SAVR) represents a third alternative with potential advantages over conventional SAVR.[2] Most studies have shown no difference in survival or major complications, but there is evidence to suggest that mis-SAVR might be associated with a lower risk of bleeding, less atrial fibrillation, quicker extubation, decreased length of hospital stay, less infection, and improved postoperative mobility compared with SAVR.[3,4] Although a recent Cochrane review failed to show any advantage of mis-SAVR, it was acknowledged that quality of evidence was low and the analysis did not include the more promising right anterior mini-thoracotomy (RAMT) approach for mis-SAVR.[5] Despite potential advantages, mis-SAVR has not been adopted by most surgeons, and accounts for only 12% of AVR volume in the United Kingdom and 5%-10% in the United States. This is likely a result of multiple factors, including a level of comfort with the results of conventional SAVR, the increased technical complexity of mis-SAVR, the need for specialized instruments and additional training, and the lack of a randomized clinical trial showing superiority of the technique.

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Surgical Approaches

Two principal approaches are used for mini-SAVR: the upper hemisternotomy (UH) and the RAMT.

Upper hemisternotomy

Patient selection and preoperative investigations. We believe all patients who need SAVR are candidates for a UH approach. In the morbidly obese, the surgery is more challenging and should be avoided during early experience with the procedure; however, as familiarity grows, these patients might derive greater overall benefit. In addition to usual preoperative investigations, a computed tomography (CT) scan is recommended to rule out significant calcification of the ascending aorta. With aortic calcification, the ability to choose an appropriate site for cannulation and cross-clamping is more limited through the small UH incision. CT coronary angiography may also be used for young patients at low risk of coronary artery disease to avoid an invasive conventional angiogram.

Technique. A 5- to 8-cm midline incision is made over the upper sternum and a partial J-shaped sternotomy is performed with extension into the right third or fourth intercostal space. Cannulation is usually performed centrally in the distal ascending aorta and the right atrial appendage with a left ventricular vent placed through the right superior pulmonary vein. To optimize exposure through the small incision, the venous cannula can be placed percutaneously in the groin. As with conventional SAVR, valve excision and replacement are carried out using standard techniques under direct vision. Because of the limited exposure, surgical times tend to be longer than with conventional SAVR. To ameliorate this, single-dose cardioplegia, automatic knot tying with the CoreKnot device (LSI Solutions, Victor, NY) and sutureless or rapid deployment valves may be used.

Benefits. The UH approach allows surgeons to use conventional techniques through a smaller incision. The use of central cannulation without the need for specialized minimally invasive instruments allows a transition from full sternotomy SAVR to the UH approach with minimal investment in training and instruments.

RAMT

Patient selection and preoperative investigations. We believe a preoperative CT scan is an essential investigation before proceeding with a RAMT approach. Because of its technical complexity, not all patients are candidates and surgeons must be particularly selective early in their experience. It is helpful to first become facile with UH mis-SAVR before beginning to use the RAMT approach. To ensure favourable early outcomes, the following criteria should be met. First, the ascending aorta should not be displaced leftward. On axial imaging at the level of the pulmonary artery bifurcation, at least half of the aorta should be to the right of the ipsilateral sternal border. Second, at the pulmonary artery bifurcation, the aorta should be < 10 cm deep to the chest wall at the mid-clavicular line (Fig. 1A). Cannulation is most commonly performed femorally via percutaneous puncture or a small cutdown, thus CT images should confirm adequate size and absence of severe calcification of the femoral vessels (Fig. 1B).

Technique. Access into the chest is gained through a 5-cm transverse incision lateral to the sternal border, entering into the second intercostal space. Although not done in all cases, exposure can be improved by separating the third rib from the sternum at the costo-chondral junction. The right internal thoracic vessels are then ligated and divided before a soft tissue retractor is placed. Although not always necessary, a rib retractor will further facilitate exposure (Fig. 1C). Cardiopulmonary bypass can be established centrally through the mini-thoracotomy incision, or if a smaller incision is used, the femoral vessels can be cannulated. Cannula position is facilitated with the use of transesophageal echocardiogram guidance. The delivery of cardioplegia, insertion of a left ventricular vent, and application of the aortic clamp can all be done directly though the thoracotomy incision or separate small incisions.

Benefits. Studies on the outcomes of RAMT vs conventional SAVR have suggested advantages, similar to the UH approach, including lower risk of bleeding and transfusion, less postoperative respiratory complications, decreased postoperative atrial fibrillation, and shorter length of hospital stay. Additionally, there is evidence that the RAMT approach might be associated with a substantially lower risk of deep sternal wound infection, less pain and narcotic usage, improved postoperative mobility with no sternal precautions, and a superior cosmetic result (Fig. 1D).[2]

Rapid Deployment and Sutureless Valves in Mis-AVR and Outcomes

Rapid deployment and sutureless valves have been shown to facilitate the performance of mis-SAVR. Three valves have been introduced to date: the Perceval S (Liva Nova, London, United Kingdom; Fig. 2A), Enable (Medtronic, Minneapolis, MN), and Intuity Elite valve (Edwards Lifesciences, Irvine, CA) (Fig. 2B). Two of the 3 now have large worldwide use, whereas the Enable is no longer available. The Perceval valve (Liva Nova) is generally referred to as a "sutureless valve," whereas the Intuity (Edwards Lifesciences) is commonly described as a "rapid deployment valve" (RDV). The Perceval valve (Liva Nova) uses 3 temporary guiding sutures and relies on radial force from a self-expanding nitinol alloy stent to secure it within the annulus. The Intuity valve (Edwards Lifesciences) requires 3 sutures, which are tied, and it has a chromium-cobalt stent within a balloon expandable polyester-coated skirt to anchor the valve.

Compared with conventional stented bioprostheses, both of these valves have been shown to have very favourable hemodynamics. In the case of Perceval (Liva Nova), this might be because of a larger effective orifice area relative to the diameter of the valve as a result of the lack of a sewing ring (Fig. 2A). For the Intuity (Edwards Lifesciences), it has been suggested that the outflow tract is stented open by its anchoring stent providing more laminar flow through the outflow tract. Studies have also shown no difference in

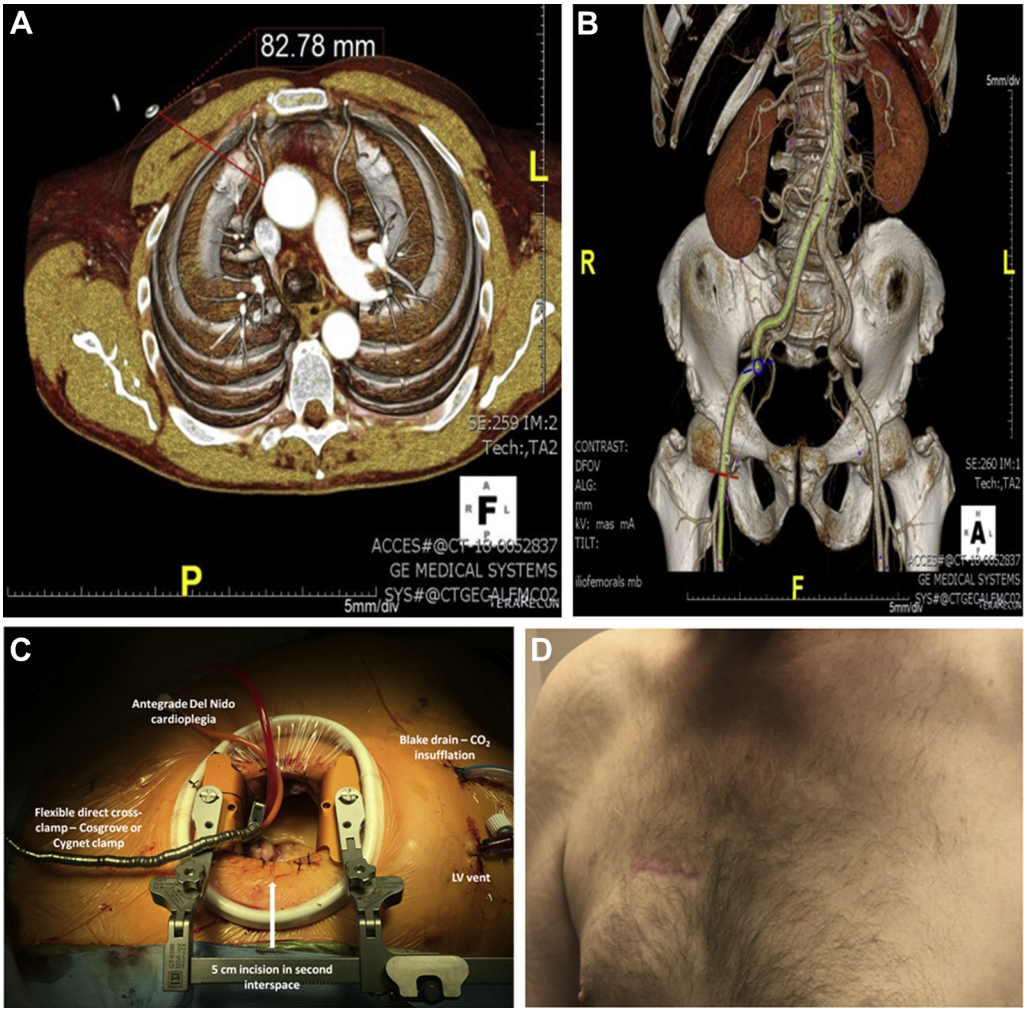

Figure 1. A computed tomography scan is used for preoperative assessment before a right anterior minithoracotomy surgical aortic valve replacement. Distance from the ascending aorta to chest wall < 9 cm suggests favourable anatomy for access (**A**). Lack of calcification of the aorta and femoral vessels indicates peripheral cannulation can be performed safely (**B**). (**C**) The right anterior mini thoracotomy incision along with the placement of the cross clamp, left ventricular vent, CO_2 insufflation, and antegrade cardioplegia. (**D**) The limited scar at postoperative follow-up.

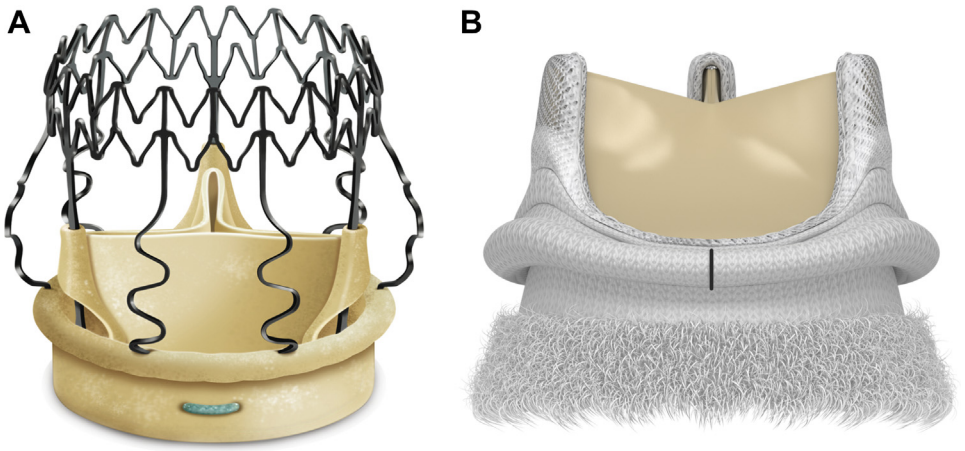

Figure 2. (**A**) The Perceval S sutureless valve (Liva Nova, London, United Kingdom). (**B**) The Intuity Elite rapid deployment valve (Edward Lifesciences, Irvine, CA). (**A**) Courtesy of Liva Nova, reproduced with permission; (**B**) courtesy of Edward Lifesciences (Canada), reproduced with permission.

survival, decreased post-operative ventilatory times, and shorter cross-clamp and cardiopulmonary bypass times with both of these valves compared with conventional stented valves.

Sutureless valves and rapid deployment valves have been shown to be particularly advantageous for select patient groups. In patients with small aortic roots, the Perceval (Liva Nova) has been shown to have better hemodynamic performance than conventional stented prostheses. This can help avoid a technically challenging and higher-risk root enlargement procedure. Both valves are also uniquely suited for severe aortic root calcification when placing sutures for a conventional valve is difficult. It has been shown that placement of an RDV is associated with increased risk of postoperative permanent pacemaker insertion, theorized to be caused by the effect of the radial force on the conduction system. There have also been reports of elevated stroke rates, higher gradients, and increased incidence of paravalvular leak in registry data reports of RDVs and sutureless valves, but this has not been shown in other series. Overall, the design of these valves, including their low-profile design and delivery system greatly enhance the performance of minimally invasive surgery because they are easily manoeuvred in small spaces. The efficiency of deployment also offsets the longer cross-clamp and cardiopulmonary bypass times, which have been associated with mini-SAVR as a result of technical complexity.

Mis-AVR: An Advance in Valve Surgery

Conventional open surgery with a mechanical or stented bioprosthesis remains the gold standard for low-risk patients requiring AVR, whereas transcatheter AVR has emerged as the best option for high-risk groups.[1] Mis-AVR with a rapid deployment or sutureless valve has potential advantages for patients with low- and intermediate-risk profiles. Although data are limited, there is emerging evidence to suggest that patients can undergo a mis-SAVR procedure with less risk of morbidity and an earlier return to activity. Rapid deployment and sutureless valves can facilitate these less invasive approaches by reducing technical complexity and decreasing cardiopulmonary bypass and cross-clamp times. Although experience with mis-AVR remains limited, its potential benefits might represent an evolution of SAVR and might change the surgical management of aortic stenosis in the future.

Disclosures

Dr Kent is a proctor for Liva Nova. The remaining authors have no conflicts of interest to disclose.

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Supplementary Material

To access the supplementary material accompanying this article, visit the online version of the *Canadian Journal of Cardiology* at www.onlinecjc.ca and at https://doi.org/10.1016/j.cjca.2018.11.027.