CASE REPORT

Vol. 9 No. 2 April-June 2024

doi: 10.35366/115160

The potential for MINIAVR: an innovative approach in patients with complex conditions

El potencial de MINIAVR: un enfoque innovador en pacientes con afecciones complejas

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ABSTRACT

Ankylosing spondylitis is a chronic, inflammatory disease that rarely involves the heart, often causing aortic valve regurgitation with aortitis. Transcatheter aortic valve implantation has been explored as a treatment option, but it may not be suitable for all cases. Minimal invasive cardiac surgery highlights its potential benefits for patients with limited respiratory and renal function and chest wall deformities, emphasizing the importance of individualized assessment for innovative approaches in complex conditions.

Keywords: ankylosing spondylitis, aortic valve regurgitation, aortic valve replacement, minimally invasive cardiac surgery.

RESUMEN

La espondilitis anquilosante es una patología crónica e inflamatoria que en pocas ocasiones afecta al corazón, ocasionando insuficiencia aórtica con aortitis. Se ha explorado la opción de colocación de válvula aórtica percutánea, sin embargo, no es factible en todos los casos. La cirugía cardíaca mínimamente invasiva puede beneficiar a pacientes con función renal y respiratoria alterada, así como con deformidad torácica, se realiza énfasis en la valoración individualizada de cada paciente con características complejas.

Palabras clave: *espondilitis anquilosante, regurgitación de la válvula aórtica, sustitución de la válvula aórtica, cirugía cardíaca mínimamente invasiva.*

How to cite: De la Cerda-Belmont GA, Garza-De la Maza A, Cepeda-Flores MG, Siller-Rodríguez J, González-Zúñiga CE, Vázquez-González RM, et al. The potential for MINIAVR: an innovative approach in patients with complex conditions. Cir Card Mex. 2024; 9 (2): 65-71. https://dx.doi.org/10.35366/115160

Received: 09-08-2023. Accepted: 11-18-2023.

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INTRODUCTION

Ankylosing spondylitis (AnSp) is a chronic, inflammatory, and rheumatic disease categorized under the group of spondyloarthropathies (SPAs). It is a complex and debilitating disease with a worldwide prevalence ranging from 0.9 to 1.9%.[1,2] It predominantly affects the sacroiliac joint and spine, with less frequent involvement of peripheral joints and the possibility of non-joint manifestations.[3] Sacroiliitis represents the earliest recognized manifestation of AnSp, but it can also extend to peripheral joints and extra-articular structures. Inflammatory changes involving enthesis, the insertion point of tendons, ligaments, capsules, or fascia into bone, are considered characteristic findings in AnSp and other SPAs.[1]

Within AnSp, cardiac involvement is a relatively uncommon condition, affecting 2 to 10% of patients, and is often characterized by aortic insufficiency, aortitis, or disturbances in heart conduction.[2-4] Valvular heart disease and conduction blocks in AnSp are closely associated with aortitis and HLA-B27. Inflammation and fibrosis in the aortic root, cardiac valves, and the subaortic and interventricular septum can lead to dilation of the aortic outflow tract, valve thickening, regurgitation, and occasionally high-degree heart block.[3,5-7] It is suggested that heart rhythm disturbances are due to inflammation-induced damage to the interventricular septum wall and atrioventricular (AV) node dysfunction result from impaired arterial supply to the AV node.[3]

Aortic valve disease in AnSp often arises due to the expansion of the aortic root caused by the development of fibrous tissue along the intima. Research has shown that this inflammatory process, accompanied by platelet aggregation and excessive fibroblast activity causes proliferative endarteritis which results in fibrotic tissue thickening and aortic root dilation. Then, the process reaches the aortic annulus, and it causes the basal thickening of the cusps which finally leads to aortic regurgitation (AR).[4]

It has been proposed that transcatheter aortic valve implantation (TAVI) could be a reasonable option of treatment,[4,8] especially in patients with ankylosed cervical spine, restricted neck motion and difficult airway management;[9] it is worth noting that TAVI for isolated chronic AR poses challenges due to aortic annulus and root dilation and lack of sufficient leaflet calcification in many patients. Risks associated with TAVI for AR treatment include a high incidence of the need for a second valve,[10] transcatheter valve migration and significant paravalvular leak. TAVI is rarely considered feasible, and only in carefully selected patients with severe AR and high surgical risk, provided that valvular calcification and annular size are suitable for the transcatheter approach. However, in patients with isolated severe AR who require surgical aortic valve replacement (AVR) being candidates for surgery, TAVI should not be performed (class of recommendation III).[11] In addition, data on TAVI in patients younger than 75 years are still limited.[12]

Understanding the complexities of AnSp and its potential impact on various systems, including the cardiovascular system, is critical for effective management and patient care. This case report aims to summarize and highlight our strategy for current surgical practice in these high-risk patients.

CASE REPORT

We present a case study of a 51-year-old male with a medical history of psoriatic AnSp who experienced symptoms of spinal stiffness, pain, and bilateral knee arthritis. Despite prolonged use of nonsteroidal and steroidal anti-inflammatory drugs, he continued to suffer from multiple relapses of psoriatic lesions, leading to the initiation of monthly monoclonal antibody treatment.

In December 2020, the patient had been hospitalized and diagnosed with heart failure (HF), ischemic heart disease, and severe AR. As part of his treatment, he underwent cardiac catheterization and percutaneous transluminal coronary angioplasty of obtuse marginal coronary artery. In addition, the patient was prescribed guideline-directed medical therapy for HF, with included a neprilysin inhibitor, angiotensin receptor blocker, beta-blocker, sodium-glucose co-transporter 2 inhibitor, diuretic, and aldosterone antagonist. Considering his complex medical history, the patient was evaluated for a TAVI procedure. However, he declined this option due to personal reasons. Consequently, he was discharged with appropriate medical management and care to be provided at home. Three months later, the patient's dyspnea progressively worsened. He also developed orthopnea, paroxysmal nocturnal dyspnea, and occasional effort-related chest pain. These symptoms prompted him to seek medical attention at our facility.

Upon arrival, the patient presented with spinal stiffness and pain, as well as bilateral knee and hip arthritis. Upon cardiac auscultation, a diastolic murmur was detected, primarily localized in the aortic region; spinal mobility was severely restricted, likely stemming from the complete stiffness affecting the entire vertebral column, particularly evident in the rectification of the cervical column, and a prominent lordosis in the thoracic column; additionally, his knee joints exhibited noticeable swelling.

The echocardiograms demonstrated an enlarged left ventricle with an end-diastolic diameter of 60 mm and an ejection fraction of 49%. Additionally, severe AR was evident, with aortic jet quantified at 100% of the left ventricular outflow tract, vena contracta of 6 mm, and an aortic valve area of 2.1 cm^2 with an aortic valve characterized by fibrotic margins and thickening of the cusps. Laboratory results

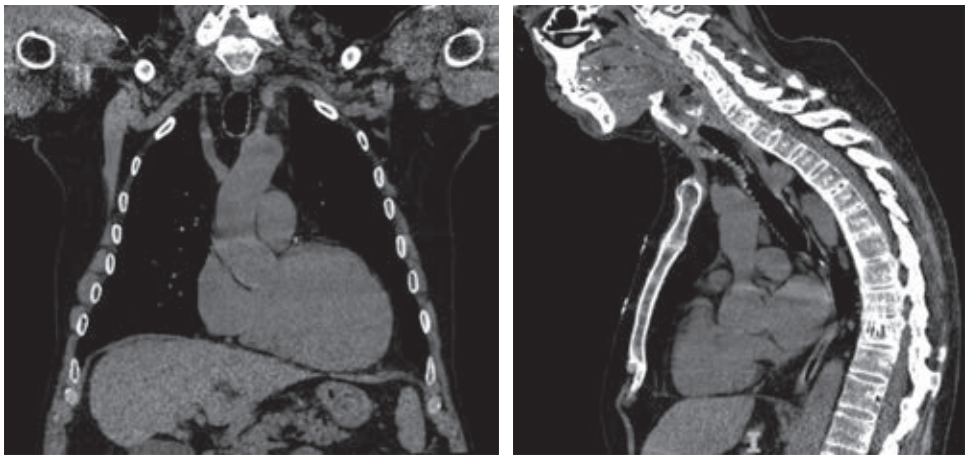

Figure 1:

CT-scan revealing vertebral body fusion of posterior processes of cervical and thoracic column, resulting in complete cervical rectification, severe thoracic lordosis and deformation of the thoracic region.

indicated potential kidney impairment with a creatinine clearance of 39.2 ml/min, and elevated inflammation markers with globular sedimentation rate of 26 mm/h, and C-reactive protein levels at 50 mg/l. Moreover, respiratory function testing exhibited a mild restrictive process, and cervical X-ray showed vertebral body fusion, producing total spine rectification in "bamboo spine". Notably, a CT scan revealed a 17 mm-long atheromatous plaque occupying 40% of the right external iliac artery; vertebral body fusion of posterior processes of cervical and thoracic column, producing total cervical rectification, extreme thoracic lordosis and thoracic deformation *(Figure 1)*.

These comprehensive findings not only offered essential insights into the patient condition, but also enable a tailored management and treatment approach. Patient medical condition, characterized by severe spinal and inflammatory compromise, restricted chest mobility, and impaired renal function, deemed conventional heart surgery a potentially dangerous option. However, considering the isolated AR without valvular calcification, the Heart-Team found TAVI unsuitable and instead opted for minimal aortic valve replacement (MINIAVR). This decision was based on the recognition that conventional heart surgery carried significant risks for the patient, while TAVI was not the appropriate course of action, given the specific aortic pathology.

In April 2021, MINIAVR was performed via a right mini thoracotomy, involving a 5 cm skin incision placed on the second intercostal space, without the need for rib resection and preserving the right internal thoracic artery *(Figure 2)*. Owing to the patient's cervical stiffness resulting in total spine rectification referred to as "bamboo spine", alongside the inherent inability to extend the cervical region, an awake intubation procedure was performed. Using flexible fiberoptic guidance with aScope 4 Broncho (Ambu Corp, Ballerup, Denmark), a 37 Fr double-lumen tube was advanced into the left bronchus. Once the correct placement

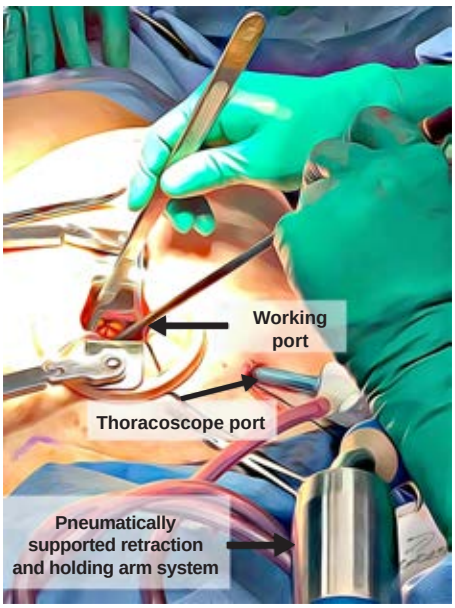

Figure 2: Surgical field perspective during minimally invasive aortic valve replacement through a right anterior thoracotomy approach. The surgeon establishes a working port via a 5 cm incision, through which the entire surgical procedure is conducted. Note the thoracoscope inserted through the second intercostal space along the midclavicular line.

of the orotracheal tube was confirmed, the anesthetic protocol was maintained.

Due to the presence of atheromatous plaque in the right external iliac artery, access to the left femoral vessels was achieved through a 1 cm inguinal incision. For femoral venous cannulation, the BioMedicus multistage cannula was used, while femoral arterial cannulation was achieved with the BioMedicus Nextgen arterial cannula (Medtronic Inc, Minneapolis, Minn). The placement of the cannula was guided by transesophageal echocardiography and fluoroscopy.

Once cardiopulmonary bypass was established using vacuum-assisted drainage (40 to 60 mmHg), a vent cannula was inserted through the right superior pulmonary vein. Throughout the entire procedure, the Aesculap EinsteinVision 3D thoracoscope was utilized (B. Braun, Melsungen, DE-HE), inserted cephalad to the working port, but through the working port itself. The patient was cooled to 36 ºC, the aorta was cross-clamped with a Chitwood aortic cross-clamp inserted through an incision in the second intercostal space, right anterior axillary line. Antegrade cardioplegic solution was administered into the aortic root, and the aortic leaflets were removed *(Figure 3)*. Subsequently, a mechanical Open Pivot aortic valve (Medtronic Inc, Minneapolis, Minn) was implanted using 2-0 polyester sutures. To secure the valve in place, an automatic knot-tying device, Cor-Knot Mini (LSI Solutions, Victor, NY), was employed *(Figure 4)*. The aortic cross clamp time was 57 minutes accompanied by 90 minutes of cardiopulmonary bypass. Due to his hemodynamic conditions and uneventful surgery, we performed ultrafast-track protocol and continue patient care process in the Intensive Care Unit (ICU). Pathology examination revealed a focal decrease in elastic fibers, fibrosis, and an increase in stromal collagen fibers. Additionally, there was a focal lymphocytic inflammatory infiltrate, primarily observed

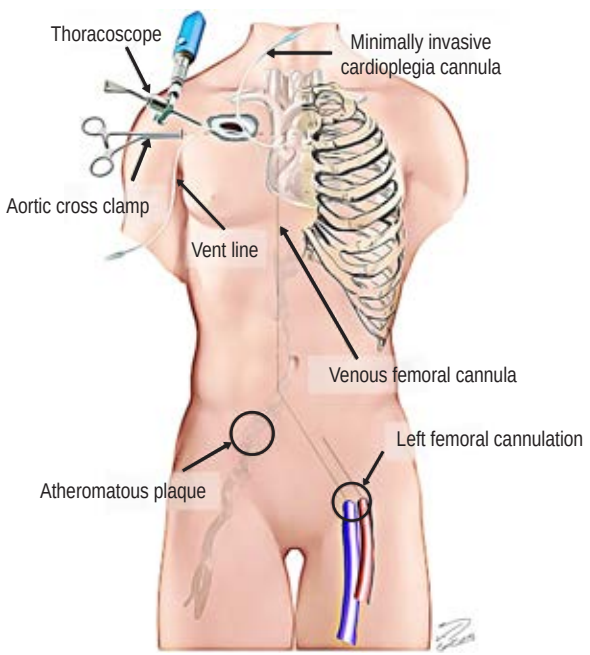

Figure 3: Operative setup for minimally invasive aortic valve replacement via right anterior thoracotomy. Thoracoscope inserted through a designated port. Aortic cross-clamp positioned through the second intercostal space along the right anterior axillary line. It is important to note left femoral cannulation employed due to the presence of iliac atheromatous disease.

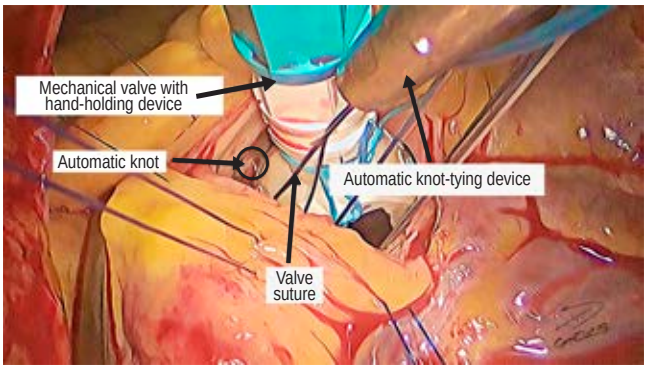

Figure 4: Thoracoscope image of intraoperative field. Mechanical aortic valve secured in place using an automatic knot-tying device.

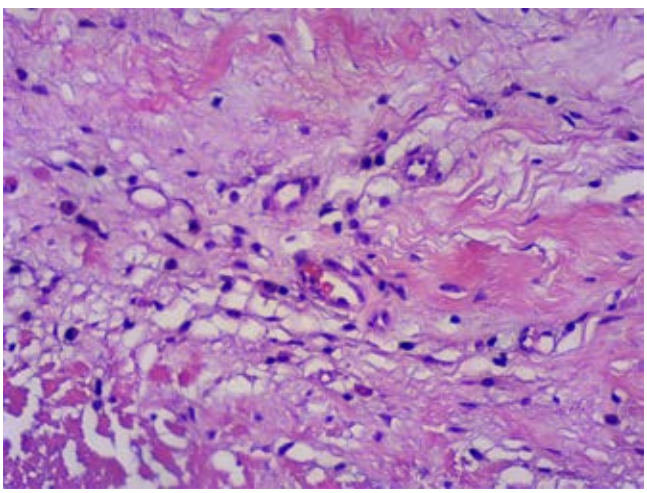

Figure 5: Aortic leaflet. Focal lymphocytic inflammatory infiltrate, primarily observed in the perivascular region.

in the peri-vascular region of the aortic leaflets *(Figure 5)*. The patient remained in the ICU for an uneventful 72-hour period; symptoms improved significantly, and he was able to be discharged home in stable condition on the sixth day following the surgery. Notably, this accomplishment marks the first instance of a minimally invasive cardiac surgery with this technique, particularly in a patient with extreme thoracic and neck deformities, reported in the state of Nuevo León up until April 2021.

COMMENT

The significance of a multidisciplinary approach, specifically the Heart-Team approach, is paramount in our medical center. We place great emphasis on conducting comprehensive reviews, thorough assessments, and providing continuous management for patients throughout the entire

diagnostic and treatment process. Integrating multiple disciplines in the pre, trans and postoperative phases is a key factor contributing to improved patient outcomes.[12]

Preoperative evaluation

Effective and consistent preoperative planning holds utmost importance as it lays the foundation for an efficient minimally invasive cardiac surgery. By proactively identifying potential complications before surgery, we can address them, promptly minimizing any hindrances to the patient's recovery. Among the specific preoperative conditions that require special attention in minimally invasive approaches are chronic lung diseases, cerebrovascular diseases, peripheral artery disease, chest wall abnormalities, lung irradiation, and previous cardiac and/or lung surgeries. Standard preoperative evaluation procedures for these cases encompass electrocardiogram, chest X-ray, complete blood laboratory tests, echocardiogram, and cardiac catheterization, resembling those conducted in full sternotomy cases. However, it is crucial to acknowledge that certain variations may exist in the preoperative investigations for standard AVR.

The role of computed tomography (CT) in the preoperative assessment of minimally invasive procedures cannot be overstated. CT scan offers valuable insights into the patient's anatomy, facilitating safer execution of the procedures.[9,11-14] Detailed information about the lungs, airway, chest wall, mediastinum, heart, major blood vessels, and peripheral vascular anatomy is made available through CT scans. Notably, CT findings related to peripheral artery disease hold particular significance. The presence of peripheral artery disease can influence the surgical approach and requires careful consideration during the planning phase.

Surgical technique

MINIAVR is performed through a right mini thoracotomy, involving a 5 cm skin incision placed on the second intercostal space, without the need of rib resection. During the procedure, utmost care is taken to preserve the right internal thoracic artery. To gain access to the femoral vessels, a 1 cm inguinal incision is made. Femoral venous and arterial cannulation is accomplished using dedicated cannula. The placement of the cannula is always guided by transesophageal echocardiography and fluoroscopy. Once cardiopulmonary bypass is established using vacuum-assisted drainage, a vent is inserted through the right superior pulmonary vein.[13-15] Throughout the entire procedure, a 3D thoracoscope is utilized, inserted cranial to the working port, but through the working port itself. The thoracoscope, also known as a thoracoscopic camera or *video*-assisted thoracoscopic surgery system, plays a crucial role in the minimal invasive aortic valve replacement technique we employ *(Figure 3)*. The role of the thoracoscope is to provide a clear and magnified view of the surgical field without the need for a large chest incision. It can be inserted through a small incision in the chest wall, between the ribs or throughout a dedicated working port, and connected to a high-definition camera or a 3D camera.[15,16] This camera displays real-time images of the surgical area on a monitor, allowing the surgeon to visualize and navigate inside the chest during the procedure. With the assistance of the thoracoscope, the surgeon can precisely access and manipulate the aortic valve and surrounding structures *(Figure 6)*. This visualization aids in accurately placing and suturing the prosthetic valve in position, ensuring proper alignment and functioning. It also helps the surgeon to identify and address any complications or challenges that may arise during the surgery. The patients are cooled to 36 ºC; subsequently, the aorta is cross-clamped with an aortic cross-clamp inserted through an incision in the second intercostal space, right anterior axillary line or through the working port with a flexible aortic clamp. Antegrade cardioplegic solution is administered into the aortic root or directly to coronary ostia *(Figure 3)*. Careful consideration is given during the aortic incision in the anterior ascending aorta to prevent extension towards the pulmonary artery. An automatic knot-tying device is always used to secure the prosthetic valve in place.

Rationale for MINIAVR

MINIAVR presents potential advantages in pulmonary function, particularly in patients with reduced respiratory reserve or poor lung function. The maintenance of sternal integrity, achieved by avoiding a full sternotomy, could prove beneficial in reducing complications associated with traditional AVR, such as prolonged recovery time and increased pain.[17]

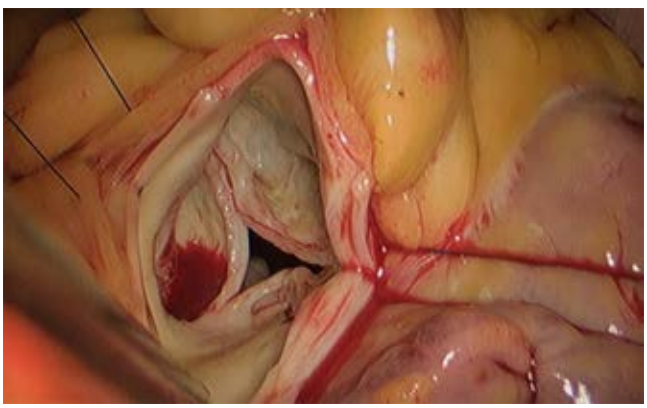

Figure 6: Thoracoscopic view of the aortic valve revealing fibrotic leaflets thickening.

Limited studies on MINIAVR in patients with poor lung function exist, but the available evidence suggests positive outcomes, demonstrating shorter ICU and hospital stays with a trend towards higher survival rates, reduced post-operative complications, implying potential benefits for lung function in this patient population. These findings highlight the potential of a minimally invasive approach in improving pulmonary outcomes for patients undergoing AVR.[17-19]

Moreover, MINIAVR has demonstrated significant benefits for patients with pre-existing renal dysfunction, a condition known to increase operative mortality and impact long-term survival in heart surgery patients. The renoprotective effect of minimally invasive surgery has been supported by evidence in mitral valve surgery.[20] Studies have reported a lower incidence of worsening on chronic kidney injury, despite longer cardiopulmonary and aortic cross clamping times, along with fewer composite complications, shorter ICU and hospital stays. Notably, minimally invasive cardiac surgery has been associated with a remarkable 60% risk reduction in the development of acute kidney injury.[21] Additionally, MINIAVR has been found to carry a lower risk of acute kidney injury compared to TAVI, further highlighting its potential to provide better outcomes and safeguard renal function in patients with renal dysfunction undergoing aortic valve procedures.[22]

While TAVI is an effective and minimally invasive procedure for treating aortic stenosis in selected patients, it should be approached with caution when considering severe pure AR due to certain concerns. In a particular study involving 43 patients with severe AR where TAVI was attempted, the overall success rate was 74.4%; of note, 18% of cases required a second valve during the index procedure.[10] Furthermore, subsequent studies were reviewed in a meta-analysis of 237 patients with severe pure AR who underwent TAVI. The results showed that the procedure success ranged from 77 to 100%. However, there was a notable 7% risk of needing to implant a second device due to prosthesis migration or severe procedural AR.[23] Considering these findings, it becomes evident that TAVI in severe pure AR presents challenges and carries a risk of requiring a second valve due to various factors, including prosthesis displacement and procedural complications. As a result, careful evaluation and consideration of alternative treatment options may be necessary for patients with this specific condition.

Despite the absence of existing publications on the advantages of MINIAVR in patients with chest wall deformities, our technique has allowed us to demonstrate its feasibility, safety, and positive outcomes. Notably, we successfully applied this approach to a patient with AnSp, a condition associated with challenging chest wall anatomy. The favorable results in this patient highlight the potential benefits of MINIAVR for individuals with chest wall deformities, shedding light on a novel and effective option in cardiac surgery for this specific patient population. It is essential to recognize that chest wall deformity is often considered a relative contraindication for MINIAVR due to potential technical challenges and increased risks associated with altered chest anatomy.[14,15,24] However, our experience with this particular patient emphasizes the importance of individualized assessment and surgical expertise in determining the suitability of MINIAVR in such cases. With careful patient selection and meticulous surgical planning, our report underscores the potential of MINIAVR as an innovative and effective approach in addressing complex patient conditions, contributing valuable insights that warrant further exploration and advancement in the field of cardiac surgery.

As a conclusion, while MINIAVR merges as a decisive and innovative approach for patients with severe isolated AR and complex conditions, this report emphasizes the importance of a multidisciplinary approach (heart team), comprehensive preoperative planning, and the use of advanced imaging techniques to ensure successful outcomes in high-risk patients. It also offers potential benefits in patients with pulmonary and renal impairment. Individualized patient assessment and surgical expertise are crucial in successful MINIAVR procedures. This case report sheds light on its feasibility and warrants further exploration to advance cardiac surgery practices.

REFERENCES

1. Sieper J, Braun J, Rudwaleit M, Boonen A, Zink A. Ankylosing spondylitis: an overview. Ann Rheum Dis. 2002;61 Suppl 3(Suppl 3):iii8-iii18. doi: 10.1136/ard.61.suppl_3.iii8.
2. Yuan SM. Cardiovascular involvement of ankylosing spondylitis: report of three cases. Vascular. 2009;17(6):342-354. doi: 10.2310/6670.2009.00023.
3. Ozkan Y. Cardiac involvement in ankylosing spondylitis. J Clin Med Res. 2016;8(6):427-430. doi: 10.14740/jocmr2488w.
4. Balciunaite A, Budrikis A, Rumbinaite E, Sabaliauskiene J, Patamsyte V, Lesauskaite V. Ankylosing spondyloarthritis resulting severe aortic insufficiency and aortitis: exacerbation of ankylosing spondyloarthritis and stenosis of the main left coronary artery after mechanical aortic valve implantation with cardiopulmonary bypass. Case Rep Rheumatol. 2020;2020:9538527. doi: 10.1155/2020/9538527.
5. Ward MM. Lifetime risks of valvular heart disease and pacemaker use in patients with ankylosing spondylitis. J Am Heart Assoc. 2018;7(20):e010016. doi: 10.1161/JAHA.118.010016.
6. Eder L, Sadek M, McDonald-Blumer H, Gladman DD. Aortitis and spondyloarthritis--an unusual presentation: case report and review of the literature. Semin Arthritis Rheum. 2010;39(6):510-514. doi: 10.1016/j.semarthrit.2008.11.004.
7. Momeni M, Taylor N, Tehrani M. Cardiopulmonary manifestations of ankylosing spondylitis. Int J Rheumatol. 2011;2011:728471. doi: 10.1155/2011/728471.
8. Costanzo P, Bamborough P, Peterson M, Deva DJ, Ong G, Fam N. Transcatheter aortic valve implantation for severe pure aortic regurgitation with dedicated devices. Interv Cardiol. 2022;17:e11. doi: 10.15420/icr.2021.19.

9. Chetrit M, Khan MA, Kapadia S. State of the art management of aortic valve disease in ankylosing spondylitis. Curr Rheumatol Rep. 2020;22(6):23. doi: 10.1007/s11926-020-00898-4.
10. Roy DA, Schaefer U, Guetta V, et al. Transcatheter aortic valve implantation for pure severe native aortic valve regurgitation. J Am Coll Cardiol. 2013;61(15):1577-1584. doi: 10.1016/j.jacc.2013.01.018.
11. Otto CM, Nishimura RA, Bonow RO, et al. 2020 ACC/AHA Guideline for the management of patients with valvular heart disease: executive summary: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation. 2021;143(5):e35-e71. doi: 10.1161/CIR.0000000000000932.
12. Vahanian A, Beyersdorf F, Praz F, et al; ESC/EACTS Scientific Document Group. 2021 ESC/EACTS Guidelines for the management of valvular heart disease. Eur Heart J. 2022;43(7):561-632. doi: 10.1093/eurheartj/ehab395.
13. Glauber M, Ferrarini M, Miceli A. Minimally invasive aortic valve surgery: state of the art and future directions. Ann Cardiothorac Surg. 2015;4(1):26-32. doi: 10.3978/j.issn.2225-319X.2015.01.01.
14. Klein P, Klop IDG, Kloppenburg GLT, van Putte BP. Planning for minimally invasive aortic valve replacement: key steps for patient assessment. Eur J Cardiothorac Surg. 2018;53(suppl_2):ii3-ii8. doi: 10.1093/ejcts/ezy086.
15. Van Praet KM, van Kampen A, Kofler M, et al. Minimally invasive surgical aortic valve replacement: The RALT approach. J Card Surg. 2020;35(9):2341-2346. doi: 10.1111/jocs.14756.
16. Tan T, Wei P, Liu Y, et al. Safety and efficacy of two-port thoracoscopic aortic valve replacement. J Cardiothorac Surg. 2023;18(1):9. doi: 10.1186/s13019-022-02086-0.
17. Fudulu D, Lewis H, Benedetto U, Caputo M, Angelini G, Vohra HA. Minimally invasive aortic valve replacement in high risk patient groups. J Thorac Dis. 2017;9(6):1672-1696. doi: 10.21037/jtd.2017.05.21.
18. Santana O, Reyna J, Benjo AM, Lamas GA, Lamelas J. Outcomes of minimally invasive valve surgery in patients with chronic obstructive pulmonary disease. Eur J Cardiothorac Surg. 2012;42(4):648-652. doi: 10.1093/ejcts/ezs098.
19. Gosain P, Larrauri-Reyes M, Mihos CG, Escolar E, Santana O. Aortic and/or mitral valve surgery in patients with pulmonary hypertension performed via a minimally invasive approach. Interact Cardiovasc Thorac Surg. 2016;22(5):668-670. doi: 10.1093/icvts/ivw019.
20. McCreath BJ, Swaminathan M, Booth JV, et al. Mitral valve surgery and acute renal injury: port access versus median sternotomy. Ann Thorac Surg. 2003;75(3):812-819. doi: 10.1016/s0003-4975(02)04502-2.
21. Valdez GD, Mihos CG, Santana O, et al. Incidence of postoperative acute kidney injury in patients with chronic kidney disease undergoing minimally invasive valve surgery. J Thorac Cardiovasc Surg. 2013;146(6):1488-1493. doi: 10.1016/j.jtcvs.2013.06.034.
22. Haldenwang P, Trampisch M, Schlomicher M, et al. Risk factors for acute kidney injury following TA-TAVI or minimally invasive aortic valve replacement: which procedure is less kidney damaging in elderly patients? Thorac Cardiovasc Surg. 2014;62(6):482-488. doi: 10.1055/s-0034-1376201.
23. Franzone A, Piccolo R, Siontis GCM, et al. Transcatheter aortic valve replacement for the treatment of pure native aortic valve regurgitation: a systematic review. JACC Cardiovasc Interv. 2016;9(22):2308-2317. doi: 10.1016/j.jcin.2016.08.049.
24. Glauber M, Gilmanov D, Farneti PA, et al. Right anterior minithoracotomy for aortic valve replacement: 10-year experience of a single center. J Thorac Cardiovasc Surg. 2015;150(3):548-56.e2. doi: 10.1016/j.jtcvs.2015.06.045.

Funding: none.

Disclosure: the authors have no conflict of interest to disclose.