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Editorial

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State of the art and new frontiers in robotic mitral valve surgery

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Abstract

The field of totally endoscopic, robotic-assisted mitral valve surgery has progressively gained popularity over the last twenty-five years. In this editorial, we sought to discuss this expanding field from a historical perspective, a technical perspective, and a training perspective.

Keywords: Robotic, mitral, valve, repair, robotic-assisted

INTRODUCTION

Each year, one-quarter of mitral valve surgeries performed in developed countries are conducted using minimally invasive techniques[1]. This is largely due to the benefits associated with smaller surgical incisions, including less postoperative pain, improved cosmetic outcomes, shorter hospital stays, and a faster return to normal levels of physical and occupational activities[2,3]. In this frame, the use of robotic assistance in a totally endoscopic fashion has progressively grown in popularity in all aspects of cardiac surgery[4-7]. Robotic-assisted mitral valve surgery has advanced from utilizing standard repair techniques for isolated degenerative lesions to a diverse portfolio of repair methods that can address almost all mitral valve pathologies at varying levels of complexity. In this editorial, we sought to outline and discuss the highlights of this expanding field from a historical perspective, a technical perspective, and a training perspective.

A HISTORICAL PERSPECTIVE

Back in 1997, the use of a voice-controlled robot called Aesop marked the beginning of robotic cardiac surgery[8]. A rapid sequence of events taking place in the following few years paved the way for the beginnings of robotic mitral valve surgery. Using a prototype of the da Vinci surgical system created by Intuitive Surgical, Inc., Carpentier and Loulmet performed the first totally computer-assisted mitral valve repair in Paris on May 7, 1998[9]. Shortly after, Mohr and Falk reported their experience in Leipzig of 5 totally computer-assisted mitral valve repairs[10]. The first da Vinci system in the United States was implemented in 1999 by Chitwood Jr.[11], and this allowed his team to begin conducting multicenter trials for robotic mitral valve surgery, which resulted in the robotic system being approved by the U.S. Food and Drug Administration[12]. In the same time span, Mehmanesh *et al.* performed the first totally endoscopic (ports only) robotic mitral valve repair using the da Vinci platform in Munich[13], while Grossi *et al.* performed the first mitral leaflet repair in North America using the Zeus platform[14,15].

Thus, in less than five years, the implementation of robotic platforms in clinical practice created a new scenario in the surgical treatment of mitral valve disease, and the era of robotic mitral valve surgery had begun. Numerous case series were published by institutions worldwide over the following years, including both single-center and multicenter studies[16-26], and recent evidence confirmed on a multi-national scale that cases are steadily growing and that clinical outcomes remain favorable[27].

A TECHNICAL PERSPECTIVE

We had the opportunity to previously report our surgical technique for various procedures that targeted the mitral valve[28-32], with excellent short-term outcomes[33]. We approach all our robotic mitral cases by placing the patient in a supine position on the operating table, with a rolled towel (or a gel pad) positioned under the right scapula and the ipsilateral arm loosely tucked slightly below the chest. This is accomplished to reduce the potential for conflicts between the robotic arms and the patient's right shoulder. The port configuration involves placing the working port and camera in the third intercostal space at the left anterior axillary line, positioning the left robotic arm port in the second intercostal space halfway between the anterior axillary line and midclavicular line, positioning the right robotic arm port in the fifth intercostal space slightly below the anterior axillary line, and placing the left atrial retractor in the fourth intercostal space, two centimeters medial to the midclavicular line. Achieving optimal triangulation between the right and left trocars with the robotic camera as well as docking the robot with precision are critical steps to maximize the airspace between the arms. In this frame, the routine positioning of the trocars can be slightly modified based on the patient's body habitus to further minimize conflicts and optimize surgical exposure. It is worth noting that we had the opportunity to perform robotic-assisted mitral valve repair on a patient with situs inversus and cardiac dextroversion, in which case we arranged the port configuration symmetrically on the left hemithorax[34]. We have also previously described our technique for unilateral percutaneous cannulation and endoaortic balloon management in robotic cases[31], for approaching redo mitral valve procedures via totally endoscopic, robotic-assisted adhesiolysis and repair[30], and for de-airing after robotic-assisted intracardiac procedures[35].

A TRAINING PERSPECTIVE

We have previously elaborated on the dynamic pathways that may lead to a career in robotic cardiac surgery[36]. Trainees who are interested in developing a robotic-assisted mitral valve surgery practice should gradually increase their exposure by shadowing faculty members at their institution who routinely perform cases using minimally invasive or robotic-assisted techniques. When their interest becomes more significant, they should seek out a more structured training journey. It is important to note that training in robotic cardiac surgery is still not commonly incorporated into cardiac surgery curricula, nor is a minimum case log of robotic-assisted cardiac procedures required for board certification[37]. As a result, aspiring cardiac surgeons interested in building foundational skills in robotic cardiac surgery must typically choose between two pathways, which are often intertwined: (1) receiving support from industry and obtaining the da Vinci System Training Certificate through dry- and wet-labs, or (2) pursuing training independently and applying for a position at an institution that has simulators and other preclinical training facilities available. There are a handful of robotic training scholarships and travel grants which are available for both trainees and young surgeons interested in setting up a robotic practice, which may represent an effective resource to provide further financial support at this early stage[36,38]. Once the surgeon has developed the necessary skills and obtained the necessary certifications, the two aforementioned paths come together, and application to clinical practice can commence. During this stage, we believe it is imperative for trainees to receive guidance from expert robotic surgeons with a flourishing clinical practice. If these experts are not available at the trainee's center, they should consider visiting experienced centers for advanced training. It is of the utmost importance to involve the entire team in the training process - with tableside assistants, scrub nurses, anesthesia teams as well as perfusion teams all receiving dedicated training in robotics. Whenever possible, consistency in the team of trained individuals working together during robotic procedures can also be considered a requirement for the success of a robotic mitral surgery program.

CONCLUSION

Badwhar *et al.* have recently identified four pillars for the establishment of a successful robotic mitral valve program[39], which should lay its foundations on (1) the ability to master complex mitral valve repair cases with a conventional approach; (2) an established experience with peripheral cardiopulmonary bypass and minimally invasive right thoracotomy; (3) proficiency in preoperative and intraoperative imaging (e.g., high-quality transesophageal echocardiography and computed tomography reconstructions); and (4) team excellence involving skilled anesthesia, nursing, and perfusion support. Adhering to these principles can establish the safety, effectiveness, and sustainability of a robotic mitral surgery program - with an ongoing and fully endorsed shift from a surgeon-centered approach to a team-based approach. A harmonious collaboration between a skilled robotic team and a supportive institution is also crucial and shall be actively pursued. In this way, a rising robotic mitral valve program can readily advance and gradually adopt more complex techniques. With the concomitant support of mentors and industry, proficiency can be reached, and patients can be offered cutting-edge care with safe, effective, and reproducible techniques combined with all the benefits that belong to the least invasive surgical approach.

DECLARATIONS

Authors' contributions

Made substantial contributions to the conception and design of the study and performed data analysis and interpretation: Amabile A, Ragnarsson S, Krane M, Geirsson A

Performed data acquisition as well as provided administrative, technical, and material support: Amabile A, Ragnarsson S, Krane M, Geirsson A

Availability of data and materials

Not applicable.

Financial support and sponsorship

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Conflicts of interest

Dr. Amabile receives consulting fees from JOMDD. Dr. Ragnarsson has no conflict of interest. Dr. Krane is a physician proctor and a member of the medical advisory board for JOMDD, a physician proctor for Peter

Duschek, a medical consultant for EVOTEC and Moderna, and has received speakers' honoraria from Medtronic and Terumo. Dr. Geirsson receives consulting fees for being a member of the Medtronic Strategic Surgical Advisory Board and from Edwards Lifesciences.

Ethical approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

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REFERENCES

1. Nissen AP, Miller III CC, Thourani VH, et al. Less invasive mitral surgery versus conventional sternotomy stratified by mitral pathology. *Ann Thorac Surg* 2021;111:819-27. DOI PubMed
2. Bush B, Nifong LW, Alwair H, Chitwood WR Jr. Robotic mitral valve surgery-current status and future directions. *Ann Cardiothorac Surg* 2013;2:814-7. DOI PubMed PMC
3. Bonatti J, Crailsheim I, Grabenwöger M, Winkler B. Minimally invasive and robotic mitral valve surgery: methods and outcomes in a 20-year review. *Innovations* 2021;16:317-26. DOI PubMed
4. Amabile A, Torregrossa G, Balkhy HH. Robotic-assisted coronary artery bypass grafting: current knowledge and future perspectives. *Minerva Cardioangiol* 2020;68:497-510. DOI PubMed
5. Balkhy HH, Amabile A, Torregrossa G. A shifting paradigm in robotic heart surgery: from single-procedure approach to establishing a robotic heart center of excellence. *Innovations* 2020;15:187-94. DOI PubMed
6. Torregrossa G, Balkhy HH. The role of robotic totally endoscopic coronary artery bypass in the future of coronary artery revascularization. *Eur J Cardiothorac Surg* 2020;58:217-20. DOI PubMed
7. Torregrossa G, Hibino N, Amabile A, Balkhy HH. Robotic surgery in the adult congenital cardiac patient: back to the future? *Innovations* 2020;15:99-100. DOI PubMed
8. Falk V, Diegler A, Walther T, Autschbach R, Mohr FW. Developments in robotic cardiac surgery. *Curr Opin Cardiol* 2000;15:378-87. DOI PubMed
9. Carpentier A, Loulmet D, Aupècle B, et al. [Computer assisted open heart surgery. First case operated on with success]. *C R Acad Sci III* 1998;321:437-42. DOI
10. Autschbach R, Onnasch JF, Falk V, et al. The Leipzig experience with robotic valve surgery. *J Card Surg* 2000;15:82-7. DOI PubMed
11. Chitwood WR Jr, Nifong LW, Elbeery JE, et al. Robotic mitral valve repair: trapezoidal resection and prosthetic annuloplasty with the da vinci surgical system. *J Thorac Cardiovasc Surg* 2000;120:1171-2. DOI PubMed
12. Nifong LW, Chitwood WR, Pappas PS, et al. Robotic mitral valve surgery: a United States multicenter trial. *J Thorac Cardiovasc Surg* 2005;129:1395-404. DOI PubMed
13. Mehmanesh H, Henze R, Lange R. Totally endoscopic mitral valve repair. *J Thorac Cardiovasc Surg* 2002;123:96-7. DOI PubMed
14. Grossi EA, Chen S, Loulmet DF. Commentary: robotic techniques in cardiac and thoracic surgery (Innovations, May/June 2020). *Innovations* 2020;15:423-4. DOI PubMed
15. Grossi EA, Lapietra A, Applebaum RM, et al. Case report of robotic instrument-enhanced mitral valve surgery. *J Thorac Cardiovasc Surg* 2000;120:1169-71. DOI PubMed
16. Tatooles AJ, Pappas PS, Gordon PJ, Slaughter MS. Minimally invasive mitral valve repair using the da Vinci robotic system. *Ann Thorac Surg* 2004;77:1978-82; discussion 82. DOI
17. Jones BA, Krueger S, Howell D, Meinecke B, Dunn S. Robotic mitral valve repair: a community hospital experience. *Tex Heart Inst J* 2005;32:143-6. PubMed PMC
18. McClure RS, Kiaii B, Novick RJ, et al. Computer-enhanced telemanipulation in mitral valve repair: preliminary experience in Canada with the da Vinci robotic system. *Can J Surg* 2006;49:193-6. PubMed PMC
19. Woo YJ. Robotic cardiac surgery. *Int J Med Robot* 2006;2:225-32. DOI PubMed
20. Folliguet T, Vanhuyse F, Constantino X, Realli M, Laborde F. Mitral valve repair robotic versus sternotomy. *Eur J Cardiothorac Surg* 2006;29:362-6. DOI PubMed
21. Murphy DA, Miller JS, Langford DA, Snyder AB. Endoscopic robotic mitral valve surgery. *J Thorac Cardiovasc Surg* 2006;132:776-81. DOI PubMed
22. Chitwood WR Jr, Rodriguez E, Chu MW, et al. Robotic mitral valve repairs in 300 patients: a single-center experience. *J Thorac Cardiovasc Surg* 2008;136:436-41. DOI PubMed

23. Cheng W, Fontana GP, De Robertis MA, et al. Is robotic mitral valve repair a reproducible approach? *J Thorac Cardiovasc Surg* 2010;139:628-33. DOI PubMed
24. Suri RM, Burkhart HM, Daly RC, et al. Robotic mitral valve repair for all prolapse subsets using techniques identical to open valvuloplasty: establishing the benchmark against which percutaneous interventions should be judged. *J Thorac Cardiovasc Surg* 2011;142:970-9. DOI PubMed
25. Mihaljevic T, Jarrett CM, Gillinov AM, et al. Robotic repair of posterior mitral valve prolapse versus conventional approaches: potential realized. *J Thorac Cardiovasc Surg* 2011;141:72-80.e1. DOI PubMed
26. Nifong LW, Rodriguez E, Chitwood WR Jr. 540 consecutive robotic mitral valve repairs including concomitant atrial fibrillation cryoablation. *Ann Thorac Surg* 2012;94:38-42; discussion 43. DOI PubMed
27. Cerny S, Oosterlinck W, Onan B, et al. Robotic cardiac surgery in Europe: status 2020. *Front Cardiovasc Med* 2021;8:827515. DOI
28. Amabile A, LaLonde MR, Komlo CMK, et al. A robotic-assisted approach to sliding plasty, neochordoplasty, and annuloplasty in a technically complex mitral valve repair. *Multimed Man Cardiothorac Surg* 2023:2023. DOI PubMed
29. Amabile A, LaLonde MR, Komlo CMK, et al. Double papillary muscle relocation: a totally endoscopic, robotic-assisted approach. *Multimed Man Cardiothorac Surg* 2022:2022. DOI PubMed
30. Amabile A, LaLonde MR, Hameed I, et al. Redo mitral valve surgery: a totally endoscopic, robotic-assisted approach for adhesiolysis and complex repair. *Multimed Man Cardiothorac Surg* 2022:2022. DOI PubMed
31. Amabile A, Hameed I, Shang M, LaLonde MR, Geirsson A, Krane M. Unilateral percutaneous cannulation and endoaortic balloon management in robotic-assisted cardiac surgery: the least invasive approach. *Multimed Man Cardiothorac Surg* 2022:2022. DOI PubMed
32. Amabile A, Morrison A, Weininger G, LaLonde MR, Krane M, Geirsson A. Robotic, totally endoscopic excision of mitral valve papillary fibroelastoma. *Multimed Man Cardiothorac Surg* 2021:2021. DOI PubMed
33. Amabile A, Morrison A, LaLonde M, et al. Two hundred robotic mitral valve repair procedures for degenerative mitral regurgitation: the Yale experience. *Ann Cardiothorac Surg* 2022;11:525-32. DOI PubMed PMC
34. Bourdillon A, Elder R, Lalonde M, Steele J, Gruber PJ, Geirsson A. Robotic mitral valve repair in a patient with cardiac dextroversion. *JTCVS Tech* 2022;11:12-6. DOI PubMed PMC
35. Amabile A, Geirsson A, Krane M, et al. De-airing maneuvers after minimally invasive and robotic-assisted intracardiac procedures. *Braz J Cardiovasc Surg* 2023. DOI PubMed
36. Torregrossa G, Amabile A, Oosterlinck W, et al. The epicenter of change: robotic cardiac surgery as a career choice. *J Card Surg* 2021;36:3497-500. DOI PubMed
37. Mitzman B, Smith BK, Varghese TK Jr. Resident training in robotic thoracic surgery. *Thorac Surg Clin* 2023;33:25-32. DOI PubMed
38. den Eynde J, Melly L, Torregrossa G, Oosterlinck W. Robotic cardiac surgery: what the young surgeon should know. *Braz J Cardiovasc Surg* 2020;35:VI-VIII. DOI
39. Darehzereshki A, Mehaffey JH, Wei LM, Badhwar V. Robotic mitral repair: maintaining quality at all levels of complexity. *Ann Cardiothorac Surg* 2022;11:583-8. DOI PubMed PMC