Robotic mitral valve repair—a high tech and digital approach leading mitral valve surgery further into the 21st century

Since the first successful robotically assisted mitral valve repair (MVR) performed by Carpentier *et al.* in Paris (1), 25 years have passed and tremendous steps have been taken in procedure development and technological advancements. The community of robotic heart surgeons has seen four iterations of the DaVinci surgical robot (Intuitive, Sunnyvale, CA, USA) which has so far been used to carry out the operation. Adjunct technology such as soft tissue retractors, the robotic left atrial retractor, preformed neochords, and titanium fasteners to anchor the annuloplasty band, just to name a few, have led to significant procedure refinement. To date, robotic MVR is routine at dedicated centers. The most active ones can be found at the U.S. East and West Coast, in Europe, in East Asia and Australia (2). All levels of mitral valve pathology have been tackled by experienced robotic surgeons. A recent meta-analysis comparing robotically assisted MVR to MVR through sternotomy has shown that despite longer cardiopulmonary bypass times and myocardial ischemic times robotically assisted MVR resulted in lower mortality, shorter stay in the intensive care unit, and decreased overall hospital stay (3). A large propensity score matched study using the Society of Thoracic Surgeons (STS) database showed lower rates of conversion to replacement, shorter intensive care unit (ICU) stay, shorter hospital length of stay and lower 30-day readmission rates in robotic MVR as compared to lateral thoracotomy approaches (4).

One main advantage of robotic approaches as compared to other less invasive methods in mitral valve surgery is the superb visualization of the mitral valve as 3D cameras have been built into surgical robots since the beginning of their application. The most important advantage lies in the enormous flexibility of the robotic end-effectors which allow for complex maneuvers on the mitral valve and on the subvalvular apparatus. This is where robotics beats other minimally invasive surgery and a recent study has clearly shown that with surgical robots more complex procedures can be carried out than with standard long shafted minimally invasive instrumentation (5). Artificial intelligence and machine learning have already reached the field of robotic surgery and integration of these concepts into surgical robots will probably shape the field significantly in the ongoing 21st century. Image-guided anatomical orientation, pathology recognition, and even automated surgical processes are potential applications of these technologies in robotic mitral surgery.

In this special series "Robotic Mitral Valve Repair", experts in the field present their techniques in very detailed videos and descriptions.

Faaz Ashraf from our team at the University of Pittsburgh Medical Center starts out with a video and paper describing the classic resectional techniques for repair of degenerative mitral valve disease. In addition to the specific approaches to repair, we tried to be very detailed about anesthesia related aspects, port placement, cannulation, access to the mitral valve, how to finish up the procedure safely.

John Massey from Paul Modi's team at the Liverpool Heart and Chest Hospital presents a video and a corresponding paper on how to use preformed neochords in robotic MVR. This so-called loop technique is very popular in non-robotic minimally invasive MVR but as the paper shows may see increased use in robotically assisted mitral surgery, specifically by surgeons who want to transition from the non-robotic mini-mitral to robotics.

Miroslav Peev from Sam Balkhy's group at the University of Chicago gives an outline of how to use hypothermic ventricular fibrillation in robotically assisted mitral valve surgery, a very valuable method in cases such as redos where aortic crossclamping or the endoballoon are difficult or contraindicated.

We invited Norihiko Ishikawa from the NewHeart Watanabe Institute in Tokyo, Japan to tell us about some secrets how they managed to bring down operative times in robotic mitral valve surgery. His group reports one of the fastest operative times globally and readers will learn about how to increase efficiency in robotically assisted cases.

Most of robotic mitral valve surgery, to date, is repair of degenerative valve disease and robotic mitral valve replacement is a rare procedure at most centers. The group from Acibadem University under the lead of Cem Alhan in Istanbul, Turkey has the world's largest experience with this operation and we are glad that Ahmet Umit Gullu contributed an article and video on their refined robotic mitral valve replacement technique.

The most advanced technique in minimally invasive mitral valve surgery is totally endoscopic MVR, a method in which

not even a minithoracotomy is applied but only ports are used. Sloane Guy refined this method at Jefferson University in Philadelphia and has recently moved to the Georgia Heart Institute. His colleague Kellen Round from Jefferson presents a detailed video and description of this superb technique which is performed through ports only without a mini-thoracotomy and also uses percutaneous cannulation techniques. Again, this is the highest level of endoscopic mitral valve surgery and probably the only one which deserves the term "totally endoscopic". We are proud to have this contribution in our special series.

I would like to thank all authors for their interesting contributions. It is the merit of the *Journal of Visualized Surgery* to bring surgical techniques to its readers and audience in nicely compiled videos and the journal can claim to be one of the most innovative educational media to date. The authors of our special series thank the *JOVS* for the opportunity to present basic and advanced techniques in robotic mitral valve surgery in a dedicated section of the journal. As an open access journal *JOVS* enables the interested surgeon to easily read their articles and watch the corresponding videos. Spread of the information should also be facilitated if the readers distribute links to our articles in their own teams and networks.

We think that robotics carries a huge potential for mitral valve surgery specifically in light of the fact that 13 new companies are testing their surgical robots in early experimental or even clinical studies. There is a bright future ahead for this field and we strongly encourage colleagues to embrace robotic and digital technology for further procedure refinement and improvement of quality in minimally invasive cardiac surgery.

Acknowledgments

I would like to acknowledge all surgeons and teams who have pioneered robotic cardiac surgery and who have contributed to the development of robotic mitral valve surgery.
Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the editorial office, *Journal of Visualized Surgery* for the series "Robotic Mitral Valve Repair". The article did not undergo external peer review.

Conflicts of Interest: The author has completed the ICMJE uniform disclosure form (available at https://jovs.amegroups.com/article/view/10.21037/jovs-23-35/coif). The series "Robotic Mitral Valve Repair" was commissioned by the editorial office without any funding or sponsorship. J.B. served as the unpaid Guest Editor of the series. The author has no other conflicts of interest to declare.

Ethical Statement: The author is accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Johannes Bonatti

Johannes Bonatti[1,2]^, MD
[1]*Division of Cardiac Surgery, Department of Cardiothoracic Surgery, University of Pittsburgh School of Medicine, Pittsburgh, PA, USA;*
[2]*University of Pittsburgh Medical Center Heart and Vascular Institute, Pittsburgh, PA, USA.*
(*Email: bonattijo@upmc.edu*)

Keywords: Mitral valve disease; mitral valve repair (MVR); mitral valve replacement; minimally invasive surgery; robotic surgery

Received: 02 October 2023; Accepted: 16 November 2023; Published online: 24 November 2023.
doi: 10.21037/jovs-23-35
View this article at: https://dx.doi.org/10.21037/jovs-23-35

doi: 10.21037/jovs-23-35
Cite this article as: Bonatti J. Robotic mitral valve repair—a high tech and digital approach leading mitral valve surgery further into the 21st century. J Vis Surg 2023;9:47.

^ ORCID: 0000-0001-6577-649X.

