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CASE REPORT

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Robotically assisted mitral valve repair using the butterfly technique in a patient with a narrow chest

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Abstract

Background Minimally invasive cardiac surgery for mitral regurgitation is challenging in patients with narrow chests due to limited thoracic space. The butterfly technique can prevent systolic anterior motion in patients with degenerative mitral regurgitation and redundant posterior leaflets, but it is difficult to perform via minimally invasive cardiac surgery. Few reports have described mitral valve repair using the butterfly technique or in a narrow chest. This case report demonstrates the feasibility and utility of robotically assisted mitral valve repair using the butterfly technique in a patient with a narrow chest, addressing the challenges involved through innovative port insertion and visualization.

Case presentation A 70-year-old woman with a narrow chest (58 mm from spine to sternum) presented with shortness of breath on exertion. Transesophageal echocardiography revealed severe mitral regurgitation with posterior leaflet prolapse. Robotically assisted mitral valve repair was performed. Skin incisions were made in the third, fourth, and sixth intercostal spaces on the right anterior axillary line. A port for the atrial retractor was placed slightly medial to the right mid-clavicular line in the fifth intercostal space, inserted more shallowly than usual to achieve mitral valve exposure. The P2 leaflet was resected and reconstructed using the butterfly technique, followed by mitral annuloplasty with a semirigid partial band. The patient was discharged 6 days postoperatively with excellent valve function. One year later, she remained asymptomatic without obvious mitral regurgitation.

Conclusions Robotically assisted mitral valve repair using the butterfly technique is feasible in patients with narrow chests. Robotic assistance facilitates mitral valve exposure and manipulation in challenging anatomical conditions through enhanced dexterity and visualization.

Keywords Minimally invasive cardiac surgery, Mitral regurgitation, Mitral valve repair, Butterfly technique, Narrow chest, Robotically assisted surgery, Posterior leaflet prolapse, Port insertion, Systolic anterior motion

Background

Minimally invasive cardiac surgery (MICS) for management of mitral regurgitation (MR) is challenging in patients with narrow chests because limited thoracic space worsens the mitral valve exposure and reduces adequate workspace [1, 2]. In mitral valve repair (MVr) for MR, the butterfly technique achieves excellent early and mid-term results, preventing systolic anterior motion (SAM) in patients with degenerative MR and redundant posterior leaflets. Asai et al. reported no postoperative SAM in patient who underwent butterfly technique. Furthermore, their study indicated that the 3-year estimated survival rates, free from overall mortality and reoperation due to recurrent MR, showed no inferiority compared to

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quadrangular resection [3]. However, this complex procedure is difficult to perform via MICS. Some reports have demonstrated the feasibility of mitral valve surgery under challenging conditions using a MICS or robotic approach [4–7]. However, these reports primarily employed simple techniques, such as valve replacement, annuloplasty, and loop techniques, or achieved exposure by physically expanding the thoracic cage with a Nuss bar. Here, we report successful robotically assisted MVr using the butterfly technique in a patient with a narrow chest. We addressed these challenges through innovative port insertion and excellent visualization, without physical expanding the thoracic cavity. This report will aid surgeons involved in repairing cardiac valves in challenging conditions, including redundant leaflets and small chest cavities.

Case presentation

A 70-year-old woman presented with shortness of breath on exertion. Her medical history included percutaneous coronary intervention to the left anterior descending artery, with no evidence of in-stent restenosis. She had no pertinent family history. These characteristics did not influence our surgical approach. Transesophageal echocardiography (TEE) revealed severe MR with posterior leaflet prolapse (Video 1). Therefore, robotically assisted MVr was planned. Preoperative computed tomography was performed to assess thoracic anatomy and peripheral vasculature for robotic access planning and percutaneous cannulation, respectively. The thoracic space was narrow, measuring 58 mm from spine to sternum, with a pectum severity index of 3.98 (Fig. 1). No vascular abnormalities were identified, and thus, peripheral cannulation for cardiopulmonary bypass (CPB) was deemed appropriate.

Skin incisions were made in the third (1 cm) and sixth (1 cm) intercostal spaces for the left and right arms, respectively, and in the fourth (3.5 cm) intercostal space for the working port, along the right anterior axillary line. A 1-cm port for the atrial retractor was placed slightly medial to the right mid-clavicular line in the fifth intercostal space. This was inserted into the lower intercostal space more shallowly than usual to achieve mitral valve exposure under the narrow chest conditions. A camera was then placed through the working port. The patient-side cart of a da Vinci Xi surgical system (Intuitive, Sunnyvale, CA, USA) was docked from the patient's left side; CPB was established using femoral arterial cannulation (BioMedicus NextGen 15 Fr, Medtronic, Minneapolis, MN, USA), femoral venous cannulation (PCKC-V 18 Fr, Senko Medical Instrument Mfg. Co., Ltd., Tokyo, Japan), and internal jugular venous cannulation (BioMedicus NextGen 15 Fr, Medtronic, Minneapolis, MN, USA). The aorta was then cross-clamped, and cardiac asystole was obtained with antegrade cardioplegia.

Fig. 1 Left atrial slice on preoperative computed tomography. The distance between the spine and sternum is 58 mm

A left atrial incision was made, followed by mitral valve exposure. The P2 leaflet was myxomatous, redundant, and 25 mm high (Fig. 2A). To decrease the redundancy, the P2 leaflet was resected to achieve the intended height of the resulting P2 leaflet (approximately 15 mm) in accordance with the butterfly technique [8] (Fig. 2B, C). The cut edges were sutured with 5–0 polypropylene (Fig. 2D); sutures were added between the cut edges and the annulus to create an appropriately shaped leaflet (Fig. 2E).

The indentation between P1 and P2 formed a deep cleft and was therefore closed. Mitral annuloplasty was performed with a semirigid partial band (CG Future Annuloplasty Band; Medtronic, Minneapolis, MN, USA) using nonabsorbable 3–0 V-Loc (Covidien, Mansfield, MA, USA) continuous sutures (Fig. 2F) (Video 2).

Water testing showed good leaflet appearance and coaptation line of 7.1 mm. Intraoperative TEE after weaning from cardiopulmonary bypass revealed no SAM and no clinically significant residual MR.

The operative time was 281 min, with a cardiopulmonary bypass duration of 169 min and an aortic cross-clamp time of 118 min. The patient was discharged 6 days postoperatively. The postoperative transthoracic echocardiography showed no residual MR and mean pressure gradient of 3 mmHg. One year postoperatively, she was asymptomatic. Transthoracic echocardiography showed no obvious MR and a mean pressure gradient of 2 mmHg (Video 3).

Discussion and conclusions

The small thoracic cavities of patients with narrow chests can restrict manipulation of surgical instruments, making the delicate maneuvers required for MICS MVr more difficult to perform. Severe pectus excavatum, which similarly restricts chest anatomy, can hinder open surgery; in such cases, robotic approaches can enhance the freedom of instrumentation, thus improving mitral valve

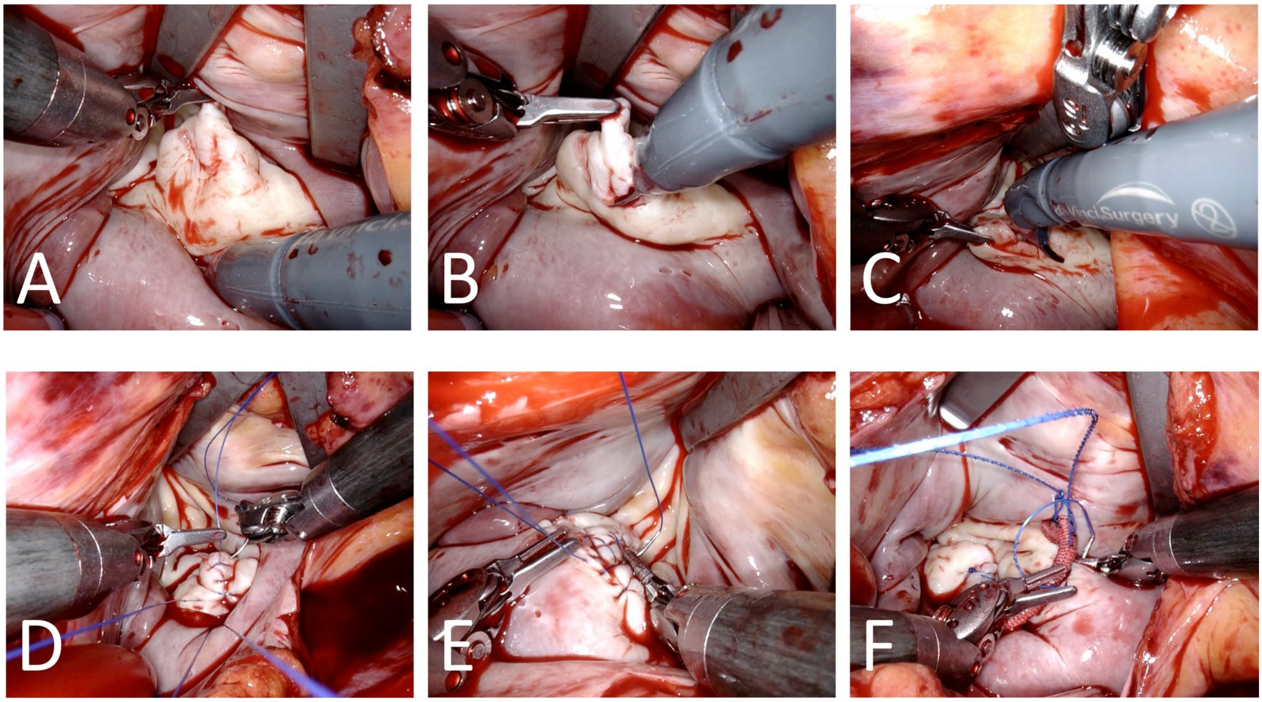

Fig. 2 Mitral valve repair procedure. **A**, The P2 leaflet was myxomatous, redundant, and 25 mm high. **B**, **C**, The prolapsing P2 leaflet was resected using the butterfly technique. **D**. The cut edges were sutured together with 5–0 polypropylene. **E**. Sutures between the cut edges and annulus. **F**. Mitral annuloplasty was performed with a semirigid partial band (CG Future Annuloplasty Ring and Band; Medtronic) using nonabsorbable 3–0 V-Loc (Covidien) continuous sutures

exposure and avoiding sternotomy-related postoperative complications [9]. The spine–sternum distance largely determines the difficulty of a MICS approach: it should be ≥80 mm for right mini-thoracotomy direct vision MICS [1]. In our patient, this distance was <60 mm and preoperative TEE showed myxomatous changes in the posterior leaflet, indicating that the volume reduction of the posterior leaflet was required to prevent SAM. We suspected that MVr with mini-thoracotomy direct vision or an endoscopic approach would be extremely difficult. Some complex repair techniques for various mitral valve pathologies have reportedly been made feasible through robotic MVr [10, 11]. Additionally, robotically assisted surgery has facilitated MVr in the context of cardiac rotation and obesity, where wound complications can be particularly problematic [4]. However, there have been few reports regarding the feasibility of robotic complex repair in patients with narrow chests, underscoring the importance of the present report. Notably, Seguchi et al. described successful implementation of robotic MVr in more than 100 complex cases involving Barlow disease, indicating that this approach is feasible in challenging anatomical conditions [12]. To facilitate mitral valve exposure, we placed an atrial retractor into the lower intercostal space more shallowly than usual for greater mobility. In our standard approach, we typically insert the left atrial retractor in the 4th intercostal space, but in this case, we inserted it in the 5th intercostal space instead of 4th and positioned it more superficially than usual. While this technique may raise concerns about intercostal injury, pain, or bleeding due to increased range of motion, we have not observed these complications in our experience. This is likely because the left atrial retractor moves less actively than the robotic arms, which handle most of the suturing and dissection. As a result, the retractor applies minimal pressure on the intercostal structures, reducing the risk of tissue damage. Careful examination of the mitral valve and identification of the resection line can be readily achieved with robotic assistance, which provides wrist-like, superior dexterity and excellent visualization through a high-definition three-dimensional camera. The surgical precision and excellent visualization of robotically assisted MVr have facilitated novel techniques with a high rate of success over several years [13]; this experience supports our implementation of an innovative shallow approach to atrial retractor placement.

When performing the butterfly procedure, precise instrument movement and detailed visualization through the camera are crucial [8]. In patients with a narrow chest, the mitral valve may shift toward the left thoracic cavity. Therefore, the camera and instruments must approach the mitral valve in a manner that allows them to navigate over this anatomical ‘ridge’ to effectively reach the target area. It is also important to assess the overall appearance of the leaflets and coaptation by water testing [8]. We accurately evaluated this appearance by simultaneously initiating cardioplegia and maintaining adequate pressure in the sinus of Valsalva. However, water testing is particularly difficult in patients with narrow chests, as the left ventricle and mitral valve fall toward the left thoracic cavity and are compressed via cardioplegia-induced dilation of the sinus of Valsalva. Hameed et al. recently illustrated the benefits of robotic assistance in cases where a depressed sternum makes exposure challenging and manipulation difficult [9]. Robotic assistance enables excellent visualization through a high-definition three-dimensional camera that extends beyond the mediastinum, which may be more challenging with the endoscopic-assisted approach.

Some important limitations should be acknowledged. First, the low level of evidence inherent in case reports limits the generalizability of our findings. Second, the 1-year operative durability of our repair was satisfactory, but long-term outcomes beyond this period remain unknown and warrant further investigation. Third, although the robotic approach can facilitate the procedure due to its dexterity and excellent visualization, the outcome partially depends on the surgeon’s skill. Therefore, the findings might not be uniformly reproducible across different surgical teams.

We have presented a patient with mitral valve regurgitation and a narrow chest who underwent robotically assisted MVr using the butterfly technique. Because a narrow chest and the butterfly technique are challenging factors in MVr, we consider robotically assisted surgery preferable in such patients. Further investigation with a larger sample size and longer follow-up is necessary. Given the increasing use of robotically assisted surgery, applications to other complex situations should be explored to determine their effectiveness.

Abbreviations

MICS	Minimally invasive cardiac surgery
MR	Mitral regurgitation
MVr	Mitral valve repair
TEE	Transesophageal echocardiography
SAM	Systolic anterior motion

Supplementary Information

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Video 1. Preoperative transesophageal echocardiography.

Video 2. Mitral valve repair using the butterfly technique.

Video 3. Transthoracic echocardiography at 1 year postoperatively.

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Author contributions

ST analyzed and interpreted the patient data and wrote the original draft. MH supervised and validated this manuscript. RK supervised and validated this manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

Data sharing is not applicable to this article because no datasets were generated or analyzed during the current study.

Declarations

Ethical approval and consent to participate

The Institutional Review Board (IRB) or equivalent ethics committee of the Sapporo Cardiovascular Clinic approved the study protocol and publication of data. IRB/ERB number and date of approval: C23-2-03, November 1, 2023.

Consent for publication

Written informed consent was obtained from the patient for publication of this case report and accompanying images.

Competing interest

The authors declare that they have no competing interests.

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