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Learning curve of robotic mitral repair: prospective two-centre study of proficiency and clinical outcomes

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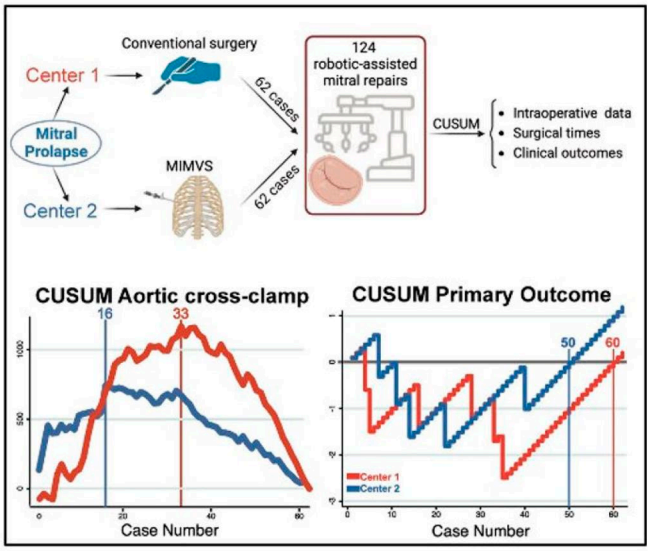
Summary

Population: First consecutive 124 robotic MV repair in 2 centres, one transitioning from MIMVS and the other from conventional surgery.

Comparison: CUSUM analyses of learning curves using clinical outcomes and surgical times.

Outcome: Successful transition to robotic surgery is feasible and safe without prior MIMVS experience, but MIMVS experience shortens the learning curve.



MV: mitral valve; MIMVS: Minimally invasive mitral valve surgery

Abstract

OBJECTIVES: Robotic-assisted mitral valve repair surgery has a steep learning curve, and it is not clear whether previous experience in minimally invasive mitral valve surgery (MIMVS) facilitates this process. We aimed to investigate the initial experience of 2 cardiac centres starting their robotic programmes, evaluating the impact of previous MIMVS experience.

METHODS: Retrospective analysis was performed for the 1st consecutive cases operated due to severe degenerative mitral valve regurgitation using the robotic surgical platform in 2 European centres, 1 transitioning from conventional surgery (centre 1) and the other from

†Both authors share first authorship to this work.

mini thoracotomy MIMVS (centre 2). Cumulative sum analysis was used to evaluate the learning process using both surgical times and a combined primary outcome including relevant intra- and postoperative results.

RESULTS: First 62 patients in each centre were included. All median surgical times were shorter in centre 2: cardiopulmonary bypass: 238 vs 115 min, $P < 0.001$; cross-clamp: 143 vs 82 min, $P < 0.001$; and total intervention: 313 vs 228 min, $P < 0.001$. The combined primary outcome showed no significant differences (9.7% vs 8%; $P = 1$). However, the turning point making the end of the learning phase was detected at the 60th case in centre 1 and at the 50th in centre 2. Regarding surgical time, the learning curve was steeper in centre 1 with both cardiopulmonary bypass and cross-clamp overcoming the learning phase after 32 cases, as compared to 16 cases in centre 2.

CONCLUSIONS: A successful robotic-assisted mitral repair programme can be safely started coming from either conventional open approach or mini thoracotomy MIMVS. However, previous mini thoracotomy MIMVS experience had positive impact on the initial learning curve.

Keywords: Robotic surgery • Mitral valve prolapse • Learning curves • Surgical outcomes • Mitral valve repair

ABBREVIATIONS

AoX	Aortic cross clamp
CABG	Coronary artery bypass grafting
CPB	Cardiopulmonary bypass
CUSUM	Cumulative sum analysis
MIMVS	Minimally invasive mitral valve surgery
MT	Mini thoracotomy
MV	Mitral valve
NYHA	New York Heart Association
RAS	Robotic-assisted surgery

INTRODUCTION

Primary mitral regurgitation due to leaflet prolapse is the most frequent indication for mitral surgery in developed countries. In the past decades, several minimally invasive mitral valve surgery (MIMVS) techniques and tools were developed to reduce surgical trauma while maintaining the excellent results of conventional surgery [1]. Concomitantly, robotic-assisted surgery (RAS) has become increasingly integral to many surgical disciplines, but its adoption in cardiac surgery has not progressed at the same pace [2]. Understanding its learning curve and finding strategies to overcome it becomes of paramount importance when initiating a RAS programme [3].

Different surgical specialties have described their learning curve when transitioning from open or endoscopic surgery to RAS [4]. In thoracic surgery, a significant learning curve has also been demonstrated, despite previous proficiency in video-assisted thoracoscopic surgery [5, 6]. However, little is known in this regard in cardiac surgery. Previous studies showed that vast experience in off-pump coronary artery bypass grafting (CABG) may soften the robotic-assisted CABG learning curve [7]. However, there is scarce information regarding the impact of previous mini thoracotomy (MT)-MIMVS experience when transitioning to the robotic platform in mitral valve (MV) surgery, one of its most interesting indications.

Cumulative sum (CUSUM) analysis is a well-known tool to study longitudinal changes in performance and learning curves of surgical procedures [8]. This methodology has been used successfully in cardiac surgery, including minimally invasive CABG and MIMVS [9, 10]. CUSUM has also been used to identify deviations from expected results, providing real-time monitoring not affected by the previous volume of cases performed [11, 12].

We aimed to investigate the learning curves of robotic-assisted MV repair, their pace and implications for patient outcomes and the factors influencing the acquisition of the required skills. Particularly, we investigated whether previous experience in MT-MIMVS may have a positive impact in this learning process.

METHODS

Ethical statement

This study was approved by the Institutional Ethics Committees of the Hospital Clínic, Barcelona, Spain: HCB/2021/0248 (3 February 2021); and the Leiden University Medical Center, Netherlands: P16.003 (14 June 2021). The need for individual written informed consent was waived in both centres.

Study population

Retrospective study analysing prospectively collected data from 2 European university hospitals: Leiden University Medical Center (centre 1) and Hospital Clínic Barcelona (centre 2). Although both are national reference centres for MV repair, centre 1 started its robotic-assisted MV programme without having a MT-MIMVS programme, while centre 2 transitioned from a long-standing MT-MIMVS programme.

We evaluated the 1st consecutive patients undergoing robotic-assisted MV repair due to leaflet prolapse in both centres, from the simultaneous initiation of their robotic programmes in late 2019. Patients requiring procedures other than concomitant atrial fibrillation ablation or patent *foramen ovale* closure were excluded. Patients with other aetiologies of mitral regurgitation were also excluded. Other exclusion criteria are detailed in the Supplementary Material S1. For direct comparisons, the same number of initial consecutive patients in each centre have been used.

The continuing results in additional patients operated after this study in centre 2 were also analysed to further explore the evolution of the learning curves beyond the limits of this comparative study.

Robotic training

Training before the start of the programme was the same for both centres and performed simultaneously, according to the robotic manufacturer recommendations. A detailed description

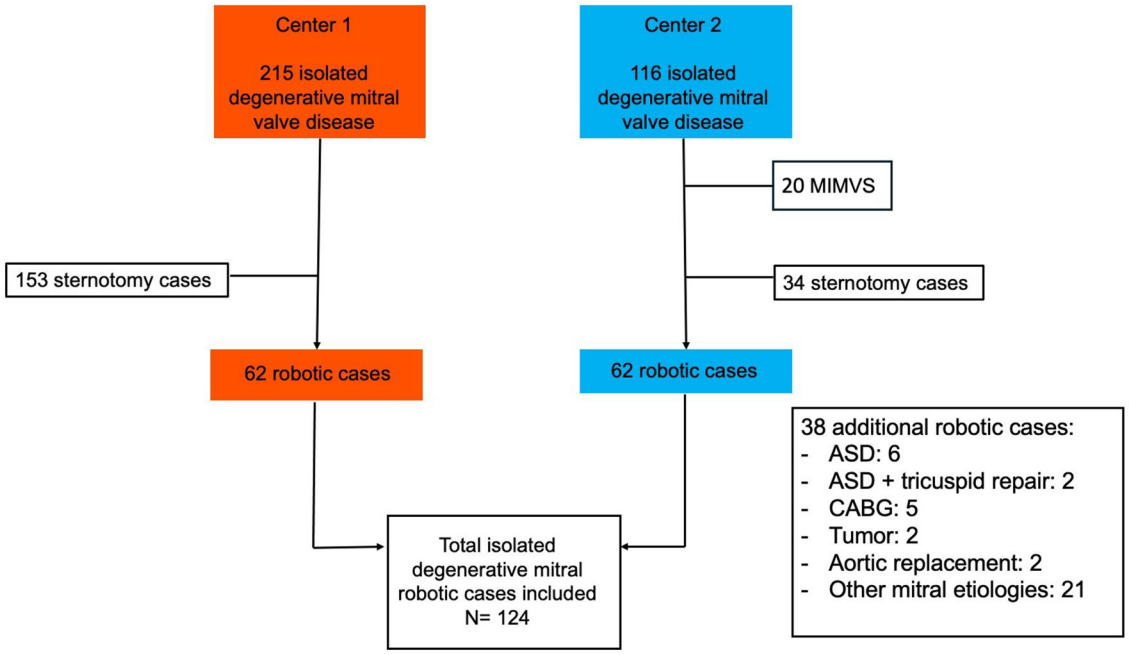


Figure 1: Flow-chart of the patients included in the study, showing the patients with degenerative MR operated using other approaches and the additional robotic cases performed during the inclusion period on each centre. ASD: atrial septal defect; CABG: coronary artery bypass grafting; MIMVS: minimally invasive mitral valve surgery; MR: mitral regurgitation.

of the training underwent by both surgical teams is provided in Supplementary Material S2.

Surgical techniques

All interventions were performed by the same single surgeon at each centre and using the da Vinci X and Xi systems (Intuitive Surgical®, USA). The description of the surgical approach is described in the Supplementary Material S3. MV repair most frequently consisted of leaflet resection and/or chordal replacement with free-hand 4-0 polytetrafluoroethylene. The choice of annuloplasty was made at the discretion each team, using flexible bands: Cosgrove (Edwards Lifesciences, USA) or semi-rigid rings: Physio II (Edwards Lifesciences, USA), Simulus (Medtronic, USA) and Memo 3D (LivaNova, Italy).

Outcomes and sources of data

Data regarding patient demographics, baseline characteristics and perioperative outcomes were obtained from prospectively maintained institutional databases.

The primary outcome consisted of a combined end point including relevant procedural and postoperative outcomes, as previously described in a similar study on MIMVS [10]. This composite outcome included any of the following during hospital admission: death, conversion to sternotomy, re-exploration for bleeding, valve-related reoperation, new renal failure requiring dialysis, stroke, perioperative myocardial infarction, low-cardiac-output syndrome with necessity for intra-aortic balloon pump or mechanical circulatory support.

Secondary outcomes consisted of operating times: total intervention time, aortic cross-clamp (AoX) duration and cardiopulmonary bypass (CPB) duration.

Statistical analysis

Descriptive statistics for categorical variables were expressed as frequency and percentage. Comparisons were performed using a Chi-squared test or the Fisher's exact test as required. Continuous variables were reported as median (25th–75th percentiles) and comparisons were performed using the Wilcoxon–Mann–Whitney test. The evolution of operative times along the experience (in quartiles according to case order) was tested using the Kruskal–Wallis test, nonparametric test for trend across ordered groups and test of the linearity assumption for an ordinal variable against category means (for continuous outcomes) or the log odds of a binary outcome. All statistical analyses were performed using STATA® (Stata Corporation, TX, USA).

Learning curves for the primary outcome were generated by CUSUM failure analysis [13]. The primary outcome was assigned if the patient experienced any of the components of the combined end-point. The CUSUM value is the actual value for the primary outcome in each case on chronological order against the expected failure rate, which was set at 10% according to previous studies [9, 10]. The moment in which the CUSUM graph accumulated enough positive outcomes to cross the baseline, after the underperforming period at the beginning, was used as the measure of the end of the learning curve.

For secondary outcomes (surgical times analyses), CUSUM methods for continuous variables were used. Patients were chronologically ordered; then the average duration for each variable of interest in each centre was calculated using the difference between each individual time minus the average time [CUSUMn = (Time n – mean time) + CUSUM (n – 1)]. Finally, the accumulated sum of differences was plotted. If the curve rises the observed duration in those cases are above the mean and if it declines, they are below. The point of proficiency was

Table 1: Preoperative characteristics

	Total ($n = 124$)	Centre 1 ($n = 62$)	Centre 2 ($n = 62$)	P-value
Age (years)	61 (51.6–66.9)	63 (54–67)	60 (48.1–66.9)	0.29
Male gender (%)	96 (77.4)	49 (79)	47 (75.8)	0.67
Body mass index (kg/m^2)	24.8 (23.4–27.6)	24.7 (23.4–27.4)	24.9 (23.5–27.8)	0.46
Creatinine (mg/dl)	0.9 (0.8–1.1)	0.9 (0.8–1.0)	1 (0.9–1.1)	0.09
Smoking (%)	12 (9.7)	3 (5.8)	9 (14.5)	0.22
Ischaemic cardiopathy (%)	4 (3.2)	1 (1.6)	3 (4.8)	0.62
Hypertension (%)	49 (39.5)	29 (46.8)	20 (32.3)	0.1
Dyslipidaemia (%)	26 (20.9)	13 (20.9)	13 (20.9)	1
Diabetes (%)	7 (5.6)	2(3.2)	5(8.1)	0.44
Prior stroke (%)	1 (0.8)	0 (0)	1 (1.6)	1
Prior atrial fibrillation (%)	14 (11.3)	4 (6.4)	10 (16.1)	0.15
Peripheral vascular disease (%)	1 (0.8)	0 (0)	1 (1.6)	1
New York Heart Association Class (%)				
I–II	99 (79.8)	55 (88.7)	44 (71)	0.01
III–IV	25 (20.1)	7 (11.3)	18 (29)	
Left ventricular ejection fraction (%)				
- Normal (>50%)	111 (89.5)	54 (88.5)	57 (93.4)	0.34
- Mild-to-moderately reduced (31–50%)	11 (10.5)	7 (11.5)	4 (6.6)	
Pulmonary hypertension (%)				
- Normal	102 (82.3)	53 (85.5)	49 (79)	0.48
- Moderate (sPAP 31–55 mmHg)	16 (12.9)	8 (12.9)	8 (12.9)	
- Severe (sPAP > 55 mmHg)	6 (4.8)	1 (1.6)	5 (8.1)	
Previous cardiac operation (%)	0	0	0	1
EuroSCORE II	0.9 (0.6–1.3)	0.7 (0.6–1.1)	0.9 (0.6–1.6)	0.1
Type of prolapse (%)				
- Anterior	9 (7.3)	4 (6.5)	5 (8.1)	0.47
- Posterior	90 (72.6%)	48 (77.4)	42 (67.7)	
- Bileaflet	25 (20.2)	10 (16.1)	15 (24.2)	

Variables expressed as median (p25-p75) or as count(%).
sPAP: systolic pulmonary artery pressure.

defined as the case number at the turning point in the slope of the resulting curve for each centre.

RESULTS

A total of 124 consecutive patients undergoing robotic-assisted MV repair on both centres (62 patients each) were included in the study cohort according to the inclusion and exclusion criteria (Fig. 1) along the study period (November 2019–October 2023 for centre 1 and November 2019–February 2022 for centre 2).

The median age for the total cohort was 61 years (51.6–66.9), with a higher proportion of male patients (77.4%), without significant differences between centres. There were no significant differences regarding cardiovascular risk profile and comorbidities, but a higher proportion of patients with New York Heart Association (NYHA) > II was found in centre 2 (11.3 vs 29%, $P = 0.014$). All preoperative characteristics are shown in detail in Table 1.

Posterior leaflet prolapse was the most frequent dysfunction in both centres (77.4 vs 66.1%, $P = 0.45$) with a progressive increase in the number of complex case along the study period (Supplementary Material, Table S3). Repair techniques differed significantly between centres. Centre 1 only used semi-rigid rings, whereas flexible bands were vastly preferred in centre 2 (90.2%). Chordal replacement was more frequent in centre 1 (96.8 vs 67.7%, $P < 0.001$) and triangular resection in centre 2 (6.4 vs 38.7%, $P < 0.001$). Surgical data are presented in Table 2.

Surgical times

There were significant differences regarding median surgical times between both centres, all being shorter in centre 2: CPB duration: 238 vs 115 min, $P < 0.001$; AoX duration: 143 vs 82 min, $P < 0.001$ and total intervention time: 313 vs 228 min, $P < 0.001$ (Fig. 2).

CUSUM graphic analysis revealed differences between centres in all surgical times (Fig. 2). For both CPB and AoX duration, centre 2 surpassed the learning phase-ascending curve after the 16th case, whereas this peak was delayed to cases 33rd and 32nd, respectively, in centre 1. The pattern for centre 1 showed significantly better CPB and ischaemic times during the initial 10 cases, followed by a steep raise afterwards. In the process of improving the technique after this initial learning phase, the curves showed different patterns in each centre. Centre 2 showed a more marked reduction in times with a directly descending curve, whereas centre 1 showed a 'plateau phase' before starting the descending phase. Total intervention time curves were similar for both centres with an initial learning phase of 16–18 cases, followed by a 'plateau phase' of ∼25 cases and a posterior mastering phase.

If we further analyse the trends of surgical times per quartile, both centres presented significant improvement over time, although absolute values were consistently shorter in centre 2 in all quartiles of experience (Fig. 3). As centres gained experience, both the median and the dispersion of surgical times were reduced in each quartile. A further analysis of the additional robotic cases performed in centre 2 after the study completion

Table 2: Intraoperative and postoperative data

	Total ($n = 124$)	Centre 1 ($n = 62$)	Centre 2 ($n = 62$)	P-value
Cardiopulmonary bypass time (min)	180 (115–254.5)	238 (193.8–308.5)	115 (94.8–142)	<0.00001
Ischaemic time (min)	108 (80.5–153.5)	143 (114–180)	82 (67–101)	<0.00001
Total surgical time (min)	258 (225–330)	313 (251.5–386)	227.5 (200–280)	<0.00001
Type of annuloplasty (%)				
- No ring	1 (0.8)	0	1 (1.6)	0.31
- Rigid ring	68 (54.8)	62 (100)	6 (9.6)	
- Flexible ring	55 (44.4)	0	55 (88.7)	
Use of neochords (%)	102 (82.3)	60 (96.8)	42 (67.7)	<0.001
Leaflet resection (%)				
- Triangular	28 (22.6)	4 (6.4)	24 (38.7)	<0.001
- Quadrangular	0	0	0	
- Sliding plasty	1 (0.8)	0	1 (1.6)	
Concomitant AF ablation (%)	7 (5.6)	5 (8)	2 (3.2)	0.44
Second AoX (%)	10 (8)	5 (8)	5 (8)	1
Extubation in the OR (%)	63 (50.8)	29 (46.8)	34 (54.8)	0.47
Mechanical ventilation (h)	0 (0–6.5)	4 (0–7)	0 (0–6.25)	0.55
Vascular complications (%)	1 (0.8)	0	1 (1.6)	0.32
Transfusion (%)	23 (18.5)	7 (11.3)	16 (25.8)	0.04
Postoperative AF (%)	32 (25.8)	17 (27.4)	15 (24.2)	0.68
ICU stay (days)	1 (1–2)	1 (1–1)	1 (1–3)	0.03
Hospital stay (days)	5 (4–7)	6 (5–7)	4 (4–6)	<0.00001
MR at discharge (%)				
Mild or less	116 (93.5)	57 (92)	59 (95.2)	0.08
Mild–Moderate	7 (5.7)	5 (8)	2 (3.2)	
Moderate	1 (0.8)	0	1 (1.6)	

Variables expressed as median (p25–p75) or as count (%).
AF: atrial fibrillation; ICU: intensive care unit; MR: mitral regurgitation; OR: operation room.

showed that improvement in surgical times continued afterwards (Supplementary Material, Fig. S1).

Primary outcome

Regarding the primary outcome, the observed incidence was 8.9%, with no significant differences in both centres (9.7% vs. 8.0%) and mostly driven by re-exploration for bleeding (6.8% in both centres). Noteworthy, there were no cases of mortality, stroke, or valve replacement, and only 1 patient required conversion (Table 3). In the success/failure CUSUM analysis, both centres presented similar curve patterns. There was an initial learning phase with a descending curve as the outcome appeared more frequently than expected (10% expected incidence), followed by an ascending curve as its incidence reduced. Both centres then accumulated increasing positive outcomes and crossed the baseline after 60 and 50 cases, respectively (Fig. 4).

In addition, other postoperative outcomes were not different between centres, as shown in Table 2. Hospital stay was significantly shorter in centre 2 (6 vs. 4 days; $P < 0.001$) despite an initial slightly longer Intensive Care Unit stay. Mitral regurgitation at discharge was none/trace in 93.5% cases, without differences between centres.

The analysis of the primary outcome in quartiles revealed a similar evolution on both centres. The largest incidence of adverse events occurred during the 1st quartile, with a continuous decreasing thereafter (Supplementary Material, Table S1). Also, a continuous reduction of mechanical ventilation and hospital stay was also found (see Supplementary Material, Table S2). Moreover, an analysis of the primary outcome on the additional cases performed after the study period in centre 2 revealed further improvement (Supplementary Material, Fig. S1).

DISCUSSION

Our study compared the learning curves of robotic-assisted MV repair in 2 centres with vast experience in MV repair surgery that started their programmes simultaneously, following the same training but with one of them transitioning directly from conventional surgery and the other from MIMVS. After analysing the first 62 cases performed at each centre, the main findings of the present study are:

1. A robotic-assisted MV repair programme can be successfully implemented with good safety and quality standards for patients, following a standardized training pathway and coming either from a previous mastery of MT-MIMVS or directly from conventional sternotomy.
2. Performance of robotic-assisted MV repair improved progressively over time, as reflected both in surgical times and clinical outcomes.
3. Previous experience in MT-MIMVS seems to soften the learning curve of robotic-assisted MV repair and shortens the duration of the procedure (CPB, AoX and total duration).

When comparing learning curves of surgical performance from both centres, we found 2 different patterns. Centre 1 showed reduced surgical times in the initial few cases, followed then by a standard curve, reaching the proficiency phase after ~30 cases. Centre 2 displayed a standard curve from the beginning but a faster improvement over time, reaching proficiency after 16 cases and showing reduced surgical times throughout the study period.

There are several potential explanations for these findings. First, centre 2 had previous experience in MT-MIMVS. As reported by other surgical specialties, previous experience in

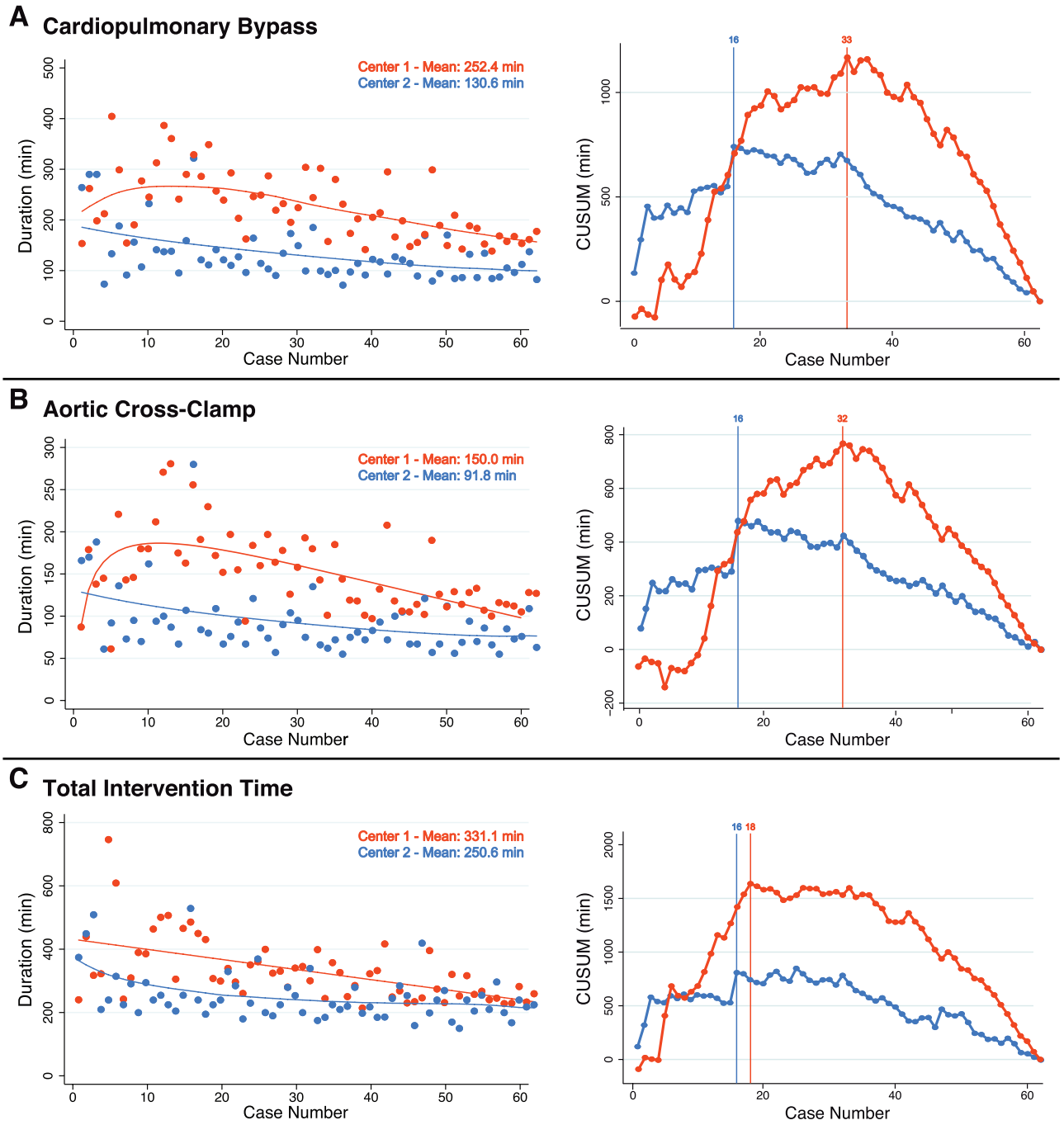


Figure 2: Graphical representation of cardiopulmonary bypass duration (**A**), cross-clamp duration (**B**) and total intervention time (**C**), compared by centre. On the left side, scatter-plot graphs showing the values for each patient and the adjusted function. On the right side, CUSUM U-shaped graphs built using each centre's own average value showing the learning curve and depicting the point of proficiency. CUSUM: cumulative sum analysis.

less-invasive surgery may soften the learning curve when transitioning to RAS, although a significant learning curve is still present [14, 15]. In the field of cardiac surgery, Van den Eynde *et al.* [7] reported that previous experience with off-pump CABG could ease the transition to robotic-assisted CABG. In the MV repair field, previous MT-MIMVS experience may facilitate several surgical steps (e.g. cannulation, myocardial protection, port placement, knot tying), thus shortening surgical times. The same may apply to the entire surgical team, particularly for the total intervention time. Second, whereas centre 2 was able to maintain a stable surgical team throughout the study, centre 1 had to change the bedside surgeon twice due to logistical reasons. Gómez-Hernández *et al.* [5] showed that the learning curve of the bedside surgeon in RAS could be longer than in video-assisted thoracoscopic surgery, independently of previous experience. Third, both centres conducted this initial experience along different timespans. In centre 1, the robotic programme was more penalized during the COVID pandemic with periods without robotic cases lasting several months, whereas centre 2, though also slowed down, was less affected (see Supplementary

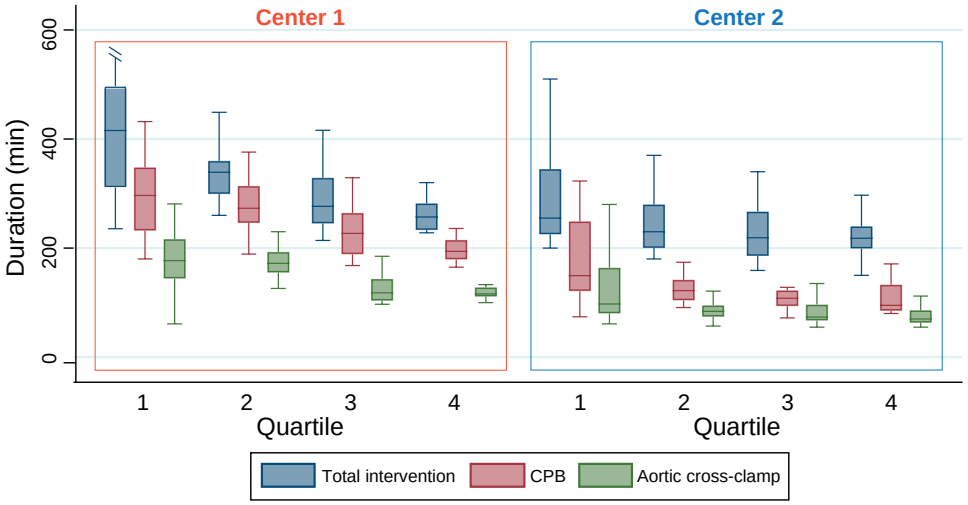


Figure 3: Evolution of all surgical times in each centre, divided by quartiles of experience, showing the continuous progressive decline in all surgical times and in its variability in both centres. CPB: cardiopulmonary bypass.

Table 3: Primary outcome

Individual subcomponents	Total ($n = 124$)	Centre 1 ($n = 62$)	Centre 2 ($n = 62$)	*P*-value
Intraoperative conversion[a] (%)	1(0.8)	1(1.6)	0	1
Failed mitral repair[b] (%)	0	0	0	1
Death (%)	0	0	0	1
Stroke (%)	0	0	0	1
Re-exploration for bleeding (%)	8(6.4)	4(6.4)	4(6.4)	1
New acute kidney injury requiring dialysis (%)	0	0	0	
Perioperative myocardial infarction (%)	1(0.8)	0	1(1.6)	1
Low cardiac output syndrome (%)	0	0	0	
Valve-related reoperation within the same hospital stay[c] (%)	1(0.8)	1(1.6)	0	1
Any of the above (%)	11(8.9)	6(9.7)	5(8.0)	1

[a]Conversion to sternotomy.
[b]Mitral replacement during index surgery.
[c]Need for mitral reintervention during the same admission due to recurrent or residual MR regardless of the final procedure performed (repair or replacement).

Material, Fig. S2). Furthermore, both centres used the robotic platform differently; while centre 1 used the robotic platform only for degenerative mitral cases, centre 2 performed also other procedures such as atrial septal defect closure, MV replacement, tricuspid valve repairs, CABG and others, with a total of 38 additional robotic cases performed during the inclusion period. This higher use of the robot and regularity could have also impacted the learning curve [13, 16]. However, we believe MT-MIMVS experience is the most important factor explaining the differences found, since they could be observed consistently from the very beginning in the 1st quartile, before all other factors could exert an effect.

Regarding the difference in performance observed on the very 1st cases, centre 1 performed their first 9 cases using the dual-console setup, in which both surgeon and proctor could use the robot. Centre 2 did not have this resource and only performed 2 cases with a proctor, who was giving advice without direct participation during the procedure. This dual-console strategy in the proctoring phase may explain the differences in the initial surgical cases and in our view reinforces the value of this approach.

Despite the clear differences found in surgical times, we found smaller differences when analysing clinical outcomes, reinforcing the safety of the implementation strategies on both centres. For our primary outcome, we used the same components and predicted risk of failure (10%), as previously described by the Leipzig group in their seminal studies of learning curves in MIMVS and CABG surgery [9, 10]. Using this preset parameter, centre 1 reached the 'improvement zone' after 60 cases, whereas centre 2 reached it after 50 cases, whereas in that study, 75–125 cases were usually required. In both centres, the most repeatedly observed complication was re-exploration for bleeding, with an incidence of 6.4%, which is in accordance with a previously published study [17]. Excellent results were obtained in both centres, with no cases of valve replacement and a very high successful repair rate. The additional analyses on the cases performed in centre 2 after completing this study confirm the stability of the improvement achieved both in the primary outcome and in surgical times, and even show further improvement in both areas with increasing experience.

One of the strengths of this study is that it combines data from 2 centres with vast experience in MV repair but different previous default approaches. Both centres started their robotic programmes simultaneously and followed the same training path, improving comparability. As centres had already mastered the MV repair learning curve, the current analysis is more reliably

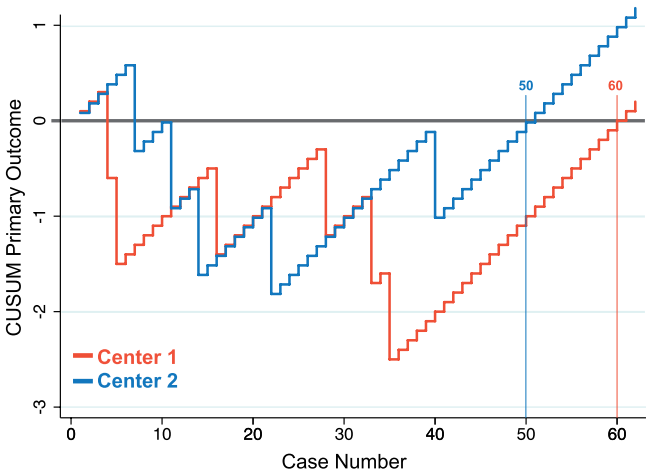


Figure 4: Graphical representation of the CUSUM failure analysis for the primary outcome in both centres. The case number when crossing the balance line (value 0) is depicted. CUSUM: cumulative sum analysis.

focused on the learning of RAS, avoiding overlapping learning curves in the analysis [18]. Some centres may opt to start a robotic programme without previous MIMVS experience, as robotic surgery is often perceived as a more accessible technique compared to endoscopic surgery. This strategy tries to avoid delaying the launch of their robotic programmes and circumvents the challenges of navigating 2 separate learning curves. To this moment, there has been no evidence analysing these 2 different strategies. However, our study presents some limitations. The first one is its observational nature, allowing for possible selection bias across both centres. Another important factor to consider is, as already discussed, the different use of the robotic platform by the 2 centres. Similar studies from more centres transitioning to RAS in the future with other different particularities may provide valuable evidence to provide useful recommendations regarding how to best start a robotic-assisted MV programme in centres with different characteristics. Third, we used each centre's mean time for the analysis rather than using a common value for both centres. This is a common methodology used in similar studies to better assess the improvement within each centre.

CONCLUSIONS

To our knowledge, this is the 1st study to analyse and compare the learning curves of robotic-assisted MV surgery adoption across 2 centres simultaneously and following the same standardized preparations, with and without prior experience in MT-MIMVS. Our findings indicate that transitioning to a robotic platform is feasible and safe even without prior MT-MIMVS experience. However, prior experience with MT-MIMVS may positively impact this transition, shortening the learning curve.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

FUNDING

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Conflict of interest: none declared.

DATA AVAILABILITY

The data will be shared on reasonable request to the corresponding author.

Author contributions

Elena Sandoval: Data curation; Methodology; Writing—original draft. **Rahul A Bhoera:** Data curation; Formal analysis; Writing—review & editing. **Anton Tomsic:** Data curation; Visualization; Writing—review & editing. **Ignacio Morales-Rey:** Writing—review & editing. **Ana Garcia-Alvarez:** Writing—review & editing. **Meindert Palmen:** Writing—review & editing. **Daniel Pereda:** Conceptualization; Formal analysis; Methodology; Software; Supervision; Validation; Visualization; Writing—review & editing.

Reviewer information

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Original article

Real-world experience with Thopaz+

The Oxford University Hospitals NHS Foundation Trust experience

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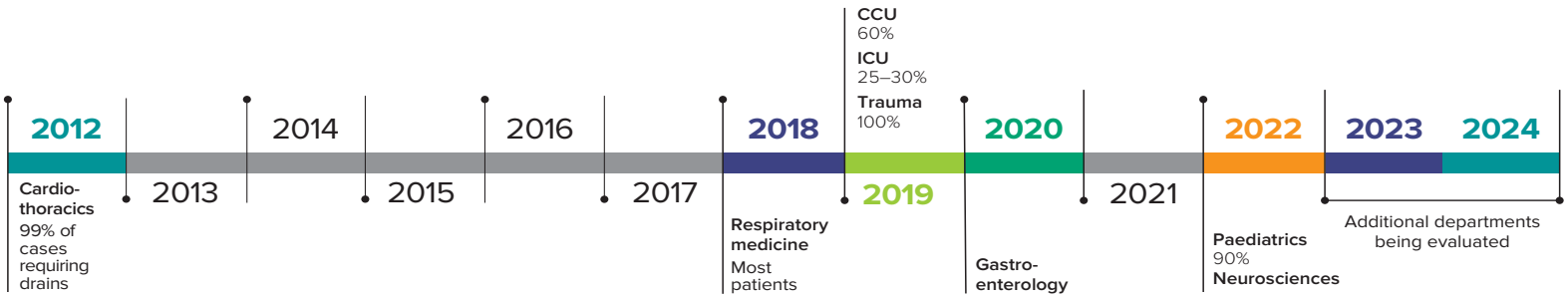
Thopaz+ is a portable digital chest drainage and monitoring system developed by Medela. It offers continuous objective monitoring of fluid loss and air leaks, which facilitates assessment of patients' progress, as well as standardisation of chest drainage management across different departments.[1] Clinical evidence has demonstrated that Thopaz+ is a useful tool in the management of patients that require chest drains and has clear clinical advantages compared with underwater seal drains.[1–3]

Thopaz+ and its predecessor, Thopaz, have been used within the Cardiothoracic Department at Oxford University Hospital NHS Trust since 2012. A report on this experience contributed to National Institute for Health and Care Excellence (NICE) Medical Technology Guidance 37.[1,4] Use of Thopaz+ in Oxford has since expanded to other departments within the trust. This document summarises the experience with Thopaz+ based on interviews with healthcare professionals (HCPs) at Oxford University Hospital NHS Trust in February/March 2024.

*Evolution of Thopaz+ use in Oxford: initial introduction by department and current usage**



*Percentage of cases using Thopaz+, where known from interviews.

CHEST DRAINAGE PROTOCOLS

Each department has a chest drain protocol based on their use of Thopaz+ or underwater seal drains, and whether active suction or physio mode is needed.

MOBILISATION

Improved and earlier mobilisation is a major advantage of Thopaz+ in relation to complications associated with immobility.

OBJECTIVE AND CONTINUOUS MONITORING LEADS TO IMPROVED DECISION-MAKING

Continuous monitoring improves chest drain decision-making by providing objective estimates/measurement of leakage. It helps determine when air leaks are resolving (allowing for earlier drain removal and discharge planning) or when further intervention is needed (such as referral to a surgeon).

LENGTH OF STAY

Digital drainage facilitates day-case procedures by giving HCPs confidence that their patients have no persistent air leaks or fluid loss.

RESPIRATORY

70% of patients following pleural intervention and 60% undergoing thoracoscopy return home the same day.

CORONARY CARE UNIT (CCU)

Length of stay of 7 days with Thopaz+ compared with 10 days with underwater seal drains.

THROUGHOUT THE PATIENT JOURNEY

Thopaz+ can be used throughout a patient's journey, which can reduce the possibility of issues and errors, because drains can become kinked or displaced whenever a device is changed. Suction can be added to a Thopaz+ device set up to provide straightforward drainage simply by pressing a button to initiate suction via the device itself.

COSTS AND EFFICIENCIES

The use of the device can lead to improved operational efficiencies and cost savings, which may justify the acquisition costs. From an evidence-based practice project in the USA, a digital air leak detection device after pulmonary lobectomy led to cost savings of $2,659 per hospital day.[5]

IMPROVED PATENT SAFETY

Thopaz+ is a closed system, reducing incidents, errors, mishaps, and infections. As a dry system, Thopaz+ prevents issues with water and device positioning. Non-medical staff can manage Thopaz+ if it is knocked over, with no patient impact. Thopaz+ has its own suction source, preventing complications with wall suction becoming displaced or unclipped.

STAFF EXPERIENCE

Precise fluid and air leak measurements including time trends, improve clinician confidence and decision-making and facilitate continuity of care. The user-friendly interface makes it easier to track air leaks and fluid output. Nursing time is saved with easy canister replacement, reduced manual monitoring, and visual and audible notifications alert HCPs of issues.

PATIENT EXPERIENCE

Patients can move around freely without nursing or healthcare assistant support. Earlier discharge reduces hospital stay. Patients can monitor their progress in terms of reducing volumes of fluid and air leaks on the display.

Summary of the real-world experience with Thopaz+

The experience of HCPs within Oxford University Hospitals NHS Foundation Trust over the past 12 years has shown that Thopaz+ has multiple benefits in the right circumstances and should be available for the vast majority of patients requiring a chest drain.

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> Overall, our experience at Oxford University Hospitals NHS Foundation trust has shown that Thopaz+ is an indispensable asset for HCPs, redefining standards of care and operational efficiency across multiple medical departments. We encourage all units using chest drains to consider making the move from underwater seal drains to Thopaz+ in the vast majority of patients requiring chest drainage.

Quotes from interviews with a number of healthcare professionals at Oxford University Hospital NHS Trust:

> From the NHS perspective, I think it probably allows us to make earlier decisions about withdrawing chest drains and getting peopleout of hospital earlier.

> There are a number of ways to recoup the costs: efficiencies in the system, less litigation because things don't go wrong, staff sickness due to back injuries, and length of stay if you can get patients home quicker.

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Read the full report:

The summary report has been written by HSJ Advisory on behalf of Medela AG, reflecting the views expressed in interviews with healthcare professionals. Medela AG funded the project and had input into the development of this report.

HSJ Advisory