

Learning Curve and Early Outcomes of Robotic Cholecystectomy: A Retrospective Cohort Study of the First 150 Cases at a Tertiary Care Hospital

Mansab Ali, Hamra Afridi, Surrendar Dawani, Madiha Masood Khan, Hazrat Bilal burki, Aiman Hilal

ABSTRACT

Objective: This study aimed to evaluate the safety and feasibility of robotic-assisted cholecystectomy using the CMR Versius system and to characterize operative performance during the initial institutional experience.

Study design and setting: This retrospective cohort study took place at Surgical Unit 4, Ward 21, Jinnah Postgraduate Medical Center, Karachi, Pakistan

Methodology: This retrospective analysis was conducted on the first 150 consecutive robotic cholecystectomy cases. These cases were performed by a trained surgeon between January 2024 and January 2026. Data were extracted from a prospectively maintained database.

Results: Out of 150 planned procedures, the majority (n=130 robotic-assisted cholecystectomies + 6 converted to Laparoscopic and 9 combined with other procedures) were completed robotically. No bile injury was noted. The mean console time was 26 minutes. The mean setup time recorded was 15 minutes. Three cases were converted to open surgery due to complex pathology (empyema, fistula). There were two procedures in patients with advanced chronic liver disease and ascites that were abandoned. Postoperative pain reported by patients was minimal, with 82.7% patients reporting Visual Analog Scale (VAS) score of 0 on postoperative day 1. Sequential operative-time analysis demonstrated improvement during the early cases followed by relative stabilization later in the series.

Conclusion: Robotic-assisted cholecystectomy using the Versius platform proved to be a safe and feasible option, even in anticipated difficult cases with minimal learning curve.

Keywords: Cholecystectomy; Learning curve; Minimally Invasive Surgery; Procedure, Robotic Surgical

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Mansab Ali

Associate Professor, Department of General Surgery
Jinnah Postgraduate Medical Centre
Email: mansab82@icloud.com

Hamra Afridi

Senior Registrar, Department of General Surgery
Jinnah Postgraduate Medical Centre
Email: Hamra.afриди@hotmail.com

Surrendar Dawani

Associate Professor, Department of General Surgery
Jinnah Postgraduate Medical Centre
Email: Surru82@hotmail.com

Madiha Masood Khan

Assistant Professor, Department of General Surgery
Jinnah Postgraduate Medical Centre
Email: Madihamasood88@gmail.com

Hazrat Bilal Burki

Professor, Department of General Surgery
Jinnah Postgraduate Medical Centre
Email: Hbburki74@gmail.com

Aiman Hilal

Clinical Fellow, Department of General Surgery
Jinnah Postgraduate Medical Centre
Email: Aiman.hilal78@gmail.com

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INTRODUCTION

Minimally invasive surgery has been widely accepted as a treatment modality for gallstone disease over the past few decades. The earlier standard laparoscopic approach was the preferred technique despite having several difficulties, such as limited depth perception, restricted movement, tremors, camera control, and a steep learning curve.^{1,2} The latest robotic-assisted surgery has effectively addressed these concerns, and its popularity is rising in hospitals that have access to this cutting-edge surgical technology. Robotic-assisted cholecystectomy provides a significant advantage of three-dimensional imaging, which provides advanced optical magnification.³ The camera is controlled by the surgeon which further overcomes the visual limitations often encountered in laparoscopy. The incorporated articulated instruments provide seven degrees of freedom, along with features of motion scaling and tremor suppression, which greatly improve accuracy in both dissection and suturing.^{4,5}

The Versius Surgical System is an innovative tele-operated robotic platform that was developed to support surgeons in performing minimally invasive procedures with greater

precision and flexibility.⁶ The traditional robotic systems relied on enclosed consoles but Versius uses an open surgeon console with hand controllers that provide intuitive control over four independent bedside units (BSUs), each of which is equipped with surgical instruments or a high-definition endoscopic camera.⁷ This setup ensures that surgeon not only remains engaged with operating room but also take benefits from robotic platform. One of the key strengths of versius surgical system is that it delivers the immersive three-dimensional HD visual feedback by a head-up display. Apart from its technical capabilities, Versius also changes the functioning of the whole operating room as a team. The Improved depth perception and spatial orientation during surgery are its primary benefits,⁸ but the system's impact extends beyond that because the surgeon communicates with the bedside team, which fosters a more collaborative and coordinated operative environment.⁵ Port placement in this system provides more flexibility because the surgeons can adopt configurations just like conventional laparoscopy instead of being locked into fixed robotic arm positions.³

Technically, Versius was designed in order to replicate the natural movement of a human arm, and provide seven degrees of freedom at the instrument tip.⁸ This feature equips the surgeons with a level of dissection and suturing control that standard laparoscopic instruments can't provide. Due to the modular design of Versius surgical system, no major infrastructure changes are needed, and each unit is positioned independently, so it is easier to adapt to different operating room layouts and to hybrid surgical approaches.¹⁰ In practice, the surgical team consists of a lead surgeon that operates from the console and a bedside assistant that handles instrument exchanges and arm positioning.⁷ The combination of robotic precision and human coordination creates a workflow that performs well in both simple and complex procedures. The Versius Surgical System® (Cambridge Medical Robotics, Cambridge, UK) was implemented in January 2024 at Jinnah Postgraduate Medical Center. This study analyzes our early experience with the first 150 robotic cholecystectomies performed using the Versius system at a Jinnah Postgraduate Medical Center in Pakistan. Since there is limited data on its clinical application and the associated learning curve, particularly from South Asian centers, our study was designed with the objective to assess the safety and feasibility of the procedures performed with this system and to evaluate the learning curve for the surgical team.

METHODOLOGY

This was a single-center, retrospective cohort study of prospectively maintained data. The study was conducted at the Jinnah Postgraduate Medical Centre in Karachi, Pakistan. The study analyzed all patients who underwent robotic-assisted cholecystectomy using the CMR Versius system between January 8, 2024, and January 18, 2026. Ethical approval for the study was obtained from the institutional review board of Jinnah Postgraduate Medical College

(Approval No. IEC/01/24/2026). Informed consent was obtained from all patients for both the procedure and the use of their anonymized data. All Adult patients over 18 years of age who were scheduled to undergo elective or urgent cholecystectomy were consecutively enrolled in this study. This was done in order to reduce selection bias and keep the sample reflective of everyday clinical practice of our ward. Patients with simple to relatively complex gall bladder diseases were included if they were fit for robotic surgical intervention. Those patients who showed clinical signs of sepsis or persistent high-grade fever were excluded. Patients who had obstructive jaundice were also excluded. The diagnosis of obstructive jaundice was made on basis of presence of clinical jaundice along with serum bilirubin levels greater than 5 mg/Dl. Similarly, patients who presented with markedly deranged liver function tests were also excluded due to the increased complexity and potential operative risk because of underlying hepatobiliary dysfunction. Those suffering from other life-threatening medical or surgical conditions that required urgent priority management were also excluded.

All procedures were performed by a single consultant surgeon (MA), with over 30 years of experience in biliary surgery. The consultant surgeon had completed structured training on the Versius Surgical System before the robotic program began at our center. The structured training was based on virtual simulation, dry-lab skill-building, and wet-lab practice. This training familiarized the surgeon with the robotic interface and instrument handling. It also played a crucial role in keeping the technique consistent throughout all the cases, especially during the early learning phase of robotic cholecystectomy. Our operative approach followed standard principles of robotic minimally invasive surgery that closely mirrored conventional laparoscopic cholecystectomy. Patients first underwent general anesthesia, and then they were positioned in reverse Trendelenburg with a slight left lateral tilt so that exposure of the gallbladder and hepatocystic triangle could be enhanced. Close attention was paid to ergonomic setup and docking of the robotic bedside units, as they helped in smooth instrument movement and reduced the chance of external arm collisions during surgery.

Port were placed at a standard configuration. An 11 mm optical port was placed at the umbilicus for the camera so that operative field could be visualized. Two 5 mm robotic working ports were placed along the midclavicular lines for proper triangulation for dissection and retraction. An additional 11 mm assistant port was placed in the epigastrium to support suction, clip application, specimen retrieval, and assistance during surgery.

The dissection of Calot's triangle was performed cautiously by using a Maryland bipolar grasper and a monopolar hook. Both of which provided precise tissue handling and controlled energy delivery. The identification of the cystic duct and cystic artery was achieved through careful dissection to

obtain a critical view of safety before clipping and division. The cystic artery was routinely secured using polymer clips. The cystic duct was individually managed according to its anatomy and diameter, using either clipping or ligation, as deemed appropriate by the operating surgeon. Robotic arm and port configurations are illustrated in Figures 1–2.

Data for this study were obtained from a prospectively maintained digital database. The database was jointly managed by the surgical unit and support staff. Maintaining the database prospectively allowed us for a systematic and real-time documentation of perioperative information for this study. A broad range of clinical and operative information were collected for analysis. Patient-related information, including demographic characteristics such as age and gender were collected. Further relevant comorbid conditions were also documented that could potentially influence perioperative outcomes. Preoperative radiological findings included ultrasonography to look for gallbladder disease. Detailed intraoperative parameters were recorded for each robotic-assisted procedure. These included robotic setup and docking times, console operating times, intraoperative findings, technical difficulties encountered during surgery, and the need for conversion to either conventional laparoscopy or open surgery. Particular attention was given to operative workflow and efficiency, as these factors are especially important during the initial adoption and learning phase of a robotic platform.

Postoperative outcomes were documented which included complications, pain scores and length of hospital stay. The final histopathological findings from the gallbladder specimens were also reviewed. Pain scores were recorded by using the Visual Analog Scale (VAS). It is a widely validated scale used for measuring pain intensity with numbering from 0 to 10. 0 indicates No pain and 10 indicates worst imaginable pain. Patients were asked to record their pain scores in a diary provided to them. Pain scores were recorded at four intervals specifically at 6 hours, 24 hours, 48 hours, and 30 days after surgery.

The primary outcome was successful completion of robotic-assisted cholecystectomy without conversion to conventional laparoscopy or open surgery and without abandonment of the procedure. Secondary outcomes included operative time, robotic system setup and docking time, intraoperative complications, conversion to conventional laparoscopy or open surgery, postoperative complications graded according to the Clavien-Dindo classification, postoperative pain scores, readmission, re-intervention, mortality, and histopathological findings. Sequential operative performance was assessed descriptively using chronological operative-time analysis.

This retrospective cohort study was reported by following the STROCSS (Strengthening the Reporting of Cohort Studies in Surgery) criteria. Statistical analysis was performed using SPSS version 26. Continuous variables were

summarized using mean $\pm$ standard deviation, while categorical variables were presented as frequencies and percentages. The primary outcome, defined as successful completion of robotic-assisted cholecystectomy without conversion or abandonment, was reported as a proportion of the total study population. Operative and postoperative outcomes were analyzed descriptively. To assess changes in operative performance during the study period, operative times were arranged chronologically according to case number and presented using a run-chart. The pattern of operative times across sequential cases was evaluated descriptively to identify changes and subsequent stabilization in operative performance. As this was a retrospective, single-arm observational study without a comparator group, no inferential comparison between robotic and laparoscopic approaches was performed.

RESULTS

A total of 150 patients were included in the cohort. The mean age was 44.8 years, with age range of 20 to 78 years. The cohort showed a slight male predominance, comprising 82 male patients (54.7%) and 68 female patients (45.3%). The mean body mass index was 26.4 kg/m², indicating that, on average, patients fell within the overweight category, shown in Table 1. Comorbid conditions were frequently observed within the study population with Hypertension being the most commonly reported comorbidity, present in 52 patients (34.7%), followed by diabetes mellitus in 41 patients (27.3%). Two patients had advanced chronic liver disease with ascites presentation. Among the 150 planned robotic-assisted cholecystectomies, the primary outcome showed that 130 (86.7%) cases were completed robotically without conversion or abandonment. A small proportion of cases required conversion. Six procedures (4.0%) were converted to standard laparoscopic cholecystectomy. The reason was dense adhesions that limited safe and effective robotic dissection. Additionally, three cases (2.0%) required conversion to an open approach. The main reason was presentation with advanced disease. Two patients had empyema complicated by fistulization to adjacent organs, including the duodenum and colon, and one case was of severe inflammatory phlegmon. After initial assessment, two patients (1.3%) with underlying Child-Pugh B/C cirrhosis and significant ascites were abandoned following port placement due to the high intraoperative risk and concern for poor outcomes. Furthermore, in 9 patients (6.0%), robotic cholecystectomy was combined with additional procedures, such as appendectomy or hernia repair. The overall safety profile observed in our cohort was favorable. There were no instances of bile duct injury or major vascular injury. No postoperative mortality was found.

The mean total console time was 26 minutes (SD $\pm$ 8.4) as shown in Graph 1. The mean robotic system setup time (from port placement to docking completion) was 15 minutes (SD $\pm$ 4.2) as shown in Graph 2. Sequential analysis of

operative time demonstrated a reduction during the early cases, followed by relative stabilization later in the series. The chronological run-chart was used to describe this pattern of operative performance; however, no definitive learning-curve endpoint was established.

Minimal discomfort was reported by most patients resulting in favorable postoperative recovery. Majority of patients (82.7%) reported a VAS pain score of 0 at 24 hours after surgery, as shown in Table 2. Only 6 patients (4.0%) experienced complications, resulting in low complication rate of robotic cholecystectomy. All complications were of minor severity (Clavien-Dindo Grade I or II). Three cases of surgical site infection and two cases of port-site hematoma occurred. Both of the cases were managed conservatively without significant clinical consequences. Only one patient developed a self-limiting bile leak that resolved with non-operative management. No patient was readmitted for any further surgical or interventional procedures. The histopathological examination of the resected specimens

revealed that the majority of patients (78%, n=117) had features consistent with chronic cholecystitis. Two specimens (1.3%) demonstrated an incidental gallbladder carcinoma.

Figure 1: CMR Versius robotic arm docked for robotic-assisted cholecystectomy



Figure 2: Port placement for right sided cholecystectomy



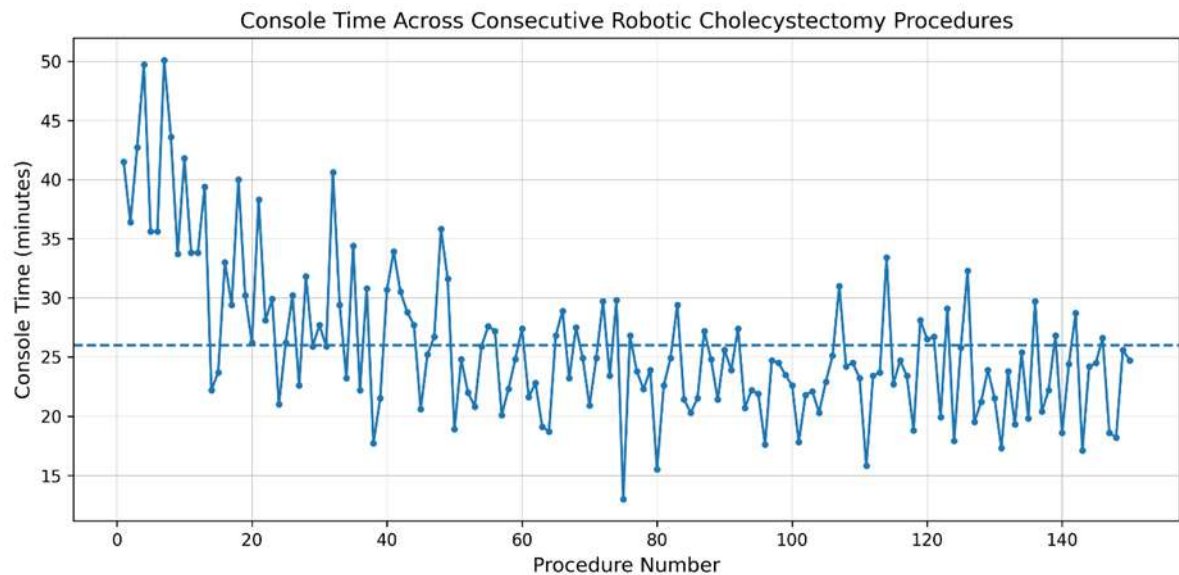
Table 1- Baseline characteristics

Variable	n (%) / Mean (range)
Gender	
Male	82 (54.7)
Female	68 (45.3)
Age (years)	44.8 (20-78)
BMI (kg/m ²)	26.4 (18.3–41.6)
Co morbidities	
Hypertension	52 (34.7)
Diabetes	41 (27.3)
Others	6 (4.0)
None	51 (34.0)

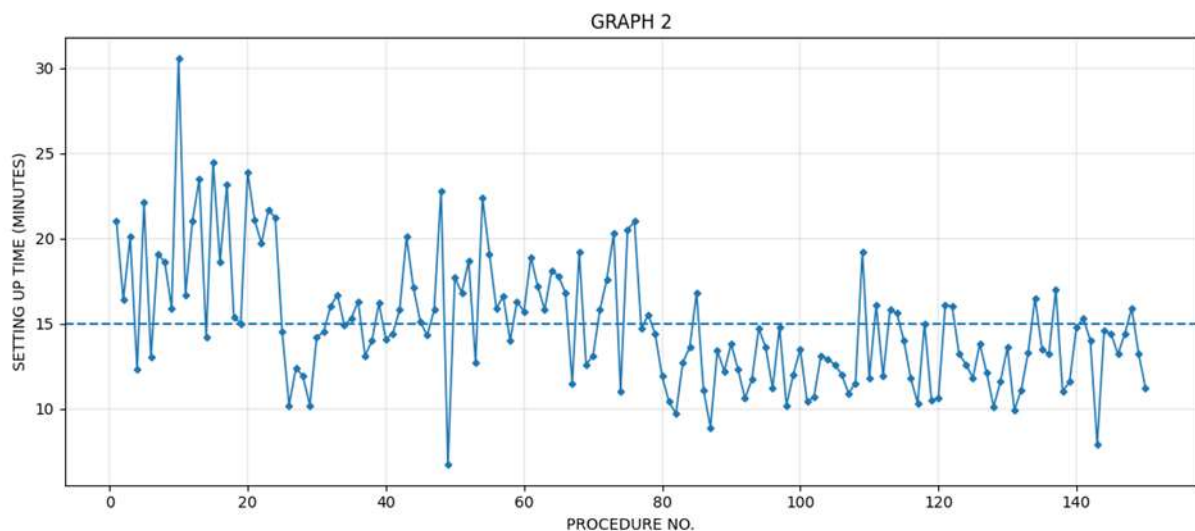
Table.2 Incidence of postoperative pain intensities

Time period	Pain Intensity	Pain Score n (%)
6 hour	No pain (VAS=0)	110 (73.3)
	Mild (VAS=1-3)	25 (16.7)
	Moderate (VAS=4-6)	15 (10.0)
	Severe (VAS=7-10)	0 (0.0)
24 hour	No pain (VAS=0)	124 (82.7)
	Mild (VAS=1-3)	23 (15.3)
	Moderate (VAS=4-6)	3 (2.0)
	Severe (VAS=7-10)	0 (0.0)
48 hour	No pain (VAS=0)	130 (86.7)
	Mild (VAS=1-3)	20 (13.3)
	Moderate (VAS=4-6)	0 (0.0)
	Severe (VAS=7-10)	0 (0.0)
30 days	No pain (VAS=0)	145(96.7)
	Mild (VAS=1-3)	5 (3.3)
	Moderate (VAS=4-6)	0 (0.0)
	Severe (VAS=7-10)	0 (0.0)

Graph 1. Run-chart analysis of console times across 150 consecutive robotic cholecystectomy procedures performed between January 2024 and January 2026. The dashed horizontal line represents the mean console time of 26 minutes



Graph 2. Run-chart analysis of setting-up times across 150 consecutive robotic cholecystectomy procedures performed between January 2024 and January 2026. The dashed horizontal line represents the mean setting-up time of 15 minutes.



DISCUSSION

Over the last two decades, robotic surgery has evolved considerably. It has become an important component of modern minimally invasive surgery. Initially, robotic surgeries gained wider acceptance in more technically demanding specialties.¹¹ These specialties included pelvic and urological surgeries because of the advantage of enhanced dexterity, improved visualization, and better ergonomics. In contrast, the adoption of robotic surgery within general surgery progressed at a relatively slower pace.⁶ Multiple factors were responsible for the slow adoption of the modern minimally invasive surgery. The main reason being the high

financial cost of robotic systems and limited accessibility in economically challenged countries like ours. The relatively small number of surgeons trained in robotic techniques also posed another challenge.⁷

In recent years, however, the introduction of newer and more versatile robotic systems has increased the interest of general surgeons in incorporating them into practice. The Latest robotic systems, like the Versius system, the da Vinci Surgical system, the Hugo RAS System, and many more, have been presented with improved instrument design and have contributed significantly to broader clinical acceptance.¹² Moreover, due to the gradual expansion of robotic training

programs and more surgeons from Pakistan undertaking training along with growing institutional investment in minimally invasive technology, robotic surgery became more accessible in a wider range of healthcare settings, including those in lower-middle-income countries like ours.¹³ Hence, this study was designed as a continuation of one of the first few detailed reports on the clinical implementation of the CMR Versius robotic system for cholecystectomy in Karachi, Pakistan.

In this retrospective cohort study, the robotic-assisted cholecystectomy was successfully completed in 130 out of 150 patients, with a success rate of 86.7%. Although the majority of procedures were completed entirely robotically, this rate was still comparatively lower than that reported in some regional studies that evaluated the same robotic platform. An Indian study reported that they performed 143 robotic cholecystectomies using the Versius Surgical System.¹ The reported rate of robotic completion was of 93.7% (134/143) in their cohort. The findings of the present study are broadly consistent with the emerging literature on robotic-assisted cholecystectomy using the Versius platform. A recent Pakistani series from Lahore involving 156 Versius-assisted cholecystectomies reported favorable short-term outcomes, with no readmissions, mortality, or 90-day morbidity and a mean console time of 63.04 ± 33.14 minutes.¹³ Similarly, a series from Gambat involving 50 patients demonstrated a reduction in docking and console times with increasing experience, although operative times remained longer than those observed in the present series.¹⁴ International early experience with the Versius system has also demonstrated high rates of robotic completion and acceptable perioperative outcomes.¹² Differences in operative times between studies may reflect variation in case complexity, surgeon experience, institutional workflow, docking protocols, and the definition of operative or console time. These differences should therefore be considered when comparing procedural efficiency across series.

A Pakistani study conducted in Lahore by Umair et al. reported that they completed 153 out of 156 procedures robotically. This demonstrates a higher completion rate of 98.07%.¹³ Several factors may explain the relatively lower robotic completion rate observed in our study cohort. One of the major reasons could be that our study represents an early institutional experience during the implementation phase of a new robotic surgical program. During this initial crucial phase, the learning curve associated with docking, instrument coordination, and intraoperative decision-making could have influenced our operative outcomes.⁵ Further, the complexity of cases included in our cohort may have contributed to the higher conversion rate. Patients with acute inflammation, dense adhesions, distorted Calot's anatomy, empyema, or previous abdominal surgeries can present significant technical challenges.⁷ These were particularly found during the initial adoption period of robotic-assisted

surgery in this cohort, leading to a higher conversion rate. The conversions to laparoscopy (4.0%) occurred primarily in the initial 6 cases, underscoring the importance of case selection during the early phase of adoption.

The differences in patient selection criteria between studies may also account for the variation in completion rates noted across the literature. Some centers initially select relatively straightforward elective cases during the early robotic learning phase, but our study included both elective and urgent cholecystectomies.^{4,5} This led to an increased operative difficulty for the robotic surgeon during the initial phase. Despite these challenges, the incidence of bile duct injury, including in cases with challenging anatomy (e.g., dense adhesions, empyema), was not found. This finding is consistent with other studies as well.^{6,15} The variations in surgical team experience, institutional workflow, operating room familiarity with robotic systems, and the availability of dedicated robotic support staff may also have influenced procedural success rates in our cohort. Despite being conducted during the early phase of robotic program implementation, the mean console time noted was of 26 minutes. It reflected a satisfactory level of procedural efficiency. This may be attributed to the surgeon's prior experience in advanced laparoscopic surgery and as the surgeon had to undergo structured robotic training, including simulation-based learning and hands-on practice.¹⁶ In addition, the relatively short setup time of approximately 15 minutes highlights one of the practical advantages of the Versius Surgical System. The modular design of the Versius surgical system and comparatively streamlined docking process made it possible.⁹ As with any newly introduced surgical technology, the efficiency of robotic-assisted procedures depends not only on the operating surgeon but also on the coordination and experience of the entire operative team.¹⁷ With increasing exposure to the robotic platform, improvements in workflow, communication, and docking efficiency were observed over time in our study duration.

The sequential analysis of operative time demonstrated improvement during the early cases followed by relative stabilization later in the series. Although this pattern may reflect increasing familiarity with the robotic platform, the present study did not use a formal CUSUM-based learning-curve analysis or establish a statistically defined proficiency threshold. Therefore, the observation that operative times appeared to stabilize during the later cases should not be interpreted as definitive evidence that the learning curve was completed after a specific number of procedures. More robust assessment of the learning curve would require case-by-case operative data analyzed using an objective statistical method, ideally with consideration of patient and procedural complexity.¹⁸ Postoperative pain outcomes were generally favorable in our study. The majority of patients in our cohort experienced minimal or no pain after robotic cholecystectomy and steady improvement was observed over time. The

proportion of pain-free patients increased from 82.7% at 24 hours to 86.7% at 48 hours. At the 30-day follow-up, 96.7% of patients were completely pain-free, while only 3.3% reported mild residual discomfort. These results indicate that robotic cholecystectomy provides effective postoperative pain control and facilitates rapid recovery.¹² The reduced postoperative pain observed in our cohort may be attributed to several advantages of robotic surgery. This may be due to enhanced instrument precision, improved tissue handling, and stable visualization. The reduced inadvertent tissue traction as compared to conventional laparoscopy is also an added advantage.⁴ Furthermore, the ergonomic design along with precise movements of the robotic platform may also contribute to more controlled dissection. The controlled dissection may in turn have ultimately decreased the tissue trauma and resulted in enhanced patient comfort during the postoperative period.³ The absence of severe postoperative pain in our study also supports the safety and minimally invasive nature of robotic-assisted cholecystectomy.

Overall, the findings of this study suggest that robotic-assisted cholecystectomy can be feasibly implemented within an evolving robotic surgery program, with an acceptable rate of procedural completion and favorable perioperative outcomes. The observed improvement in operative performance over the course of the series may reflect increasing familiarity with the robotic platform and refinement of the operative workflow.¹⁹⁻²⁰ However, these findings should be interpreted in the context of the study design and should not be considered evidence of superiority over conventional laparoscopic cholecystectomy. Nevertheless, several limitations should be considered. The retrospective design, single-center setting, and single-surgeon experience limit the generalizability of the findings. In addition, the absence of a contemporaneous laparoscopic control group limits direct comparison between the two approaches. The learning-curve assessment was based on chronological descriptive analysis of console time rather than a formal statistical method such as CUSUM; therefore, a definitive proficiency threshold could not be established. Operative performance may also have been influenced by variations in patient characteristics, disease severity, procedural complexity, and operating-room team experience across sequential cases. Finally, the economic implications and cost-effectiveness of robotic cholecystectomy were not evaluated and should be addressed in future prospective comparative studies.

CONCLUSION

In this single-center, single-surgeon experience, robotic-assisted cholecystectomy using the CMR Versius system was feasible and associated with favorable perioperative outcomes, including a low rate of postoperative complications and no bile duct injury or postoperative mortality. Sequential operative-time analysis demonstrated improvement during the early experience followed by relative stabilization;

however, this descriptive pattern does not establish a definitive learning-curve endpoint. Larger prospective comparative studies are warranted to further evaluate the clinical outcomes, learning curve, and cost-effectiveness of robotic-assisted cholecystectomy.

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Authors Contribution:

Mansab Ali: Conceptualization, study design, robotic surgeries, supervision, and critical revision of the manuscript.

Hamra Afridi: data curation, statistical analysis, interpretation of results, and manuscript drafting.

Surrendar Dawani: Patient recruitment, perioperative data acquisition, literature review, and manuscript editing

Madiha Masood Khan: Data validation, methodology development, interpretation of findings, and review of the manuscript.

Hazrat Bilal Burki: Histopathological data collection, clinical coordination, manuscript review, and administrative support.

Aiman Hilal: Project administration, overall supervision, final manuscript review, and approval of the version to be published.

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