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Robotic Cholecystectomy Remains Safe and Effective After Regular Hours: a 3 year update

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Abstract

Background

Despite growing popularity in robotic assisted surgery, access during evenings and weekends (after-hours) for non-elective operations may be restricted. A prior smaller comparison-study in 2023 found no basis for safety concerns in managing acute cholecystitis in this setting. We seek to publish additional data to help clarify the justification, if any, in restriction of robotic surgery during “after-hours”.

Methods

We performed a retrospective analysis of 161 patients undergoing robotic cholecystectomy for acute cholecystitis per 2018 Tokyo criteria by a single surgeon at multiple institutions between 2021 and 2026. Patients were grouped as “after-hours” cholecystectomy if the operation started at 17:00 hours or later, or anytime during the weekend (Saturday/Sunday). Demographic, perioperative and outcome variables were tabulated and analyzed. For illustrative purposes, data was presented as median (mean ± standard deviation) were applicable.

Results

65 after-hours and 96 regular-hours robotic cholecystectomies were included. There were no significant differences in perioperative variables between the two cohorts in terms of body mass index, age, gender, cirrhotic status, ASA score, white blood cell count, nor neutrophil percentage. With the exception of alkaline phosphatase, there were no significant differences in liver function tests. There were no significant differences in terms of operative time, estimated blood loss, length of stay, complications, nor readmissions. There were no bile duct injuries nor mortalities in either cohort.

Conclusion

Robotic cholecystectomy can be safely performed on the weekends and evenings. This updated retrospective comparison study should encourage hospitals to support round-the clock robotic surgery access.

Introduction

The past two decades has seen a rise in the implementation of robotic technology in minimally invasive cholecystectomy. Although some studies question its utility and risks, the balance of data strongly suggests its advantages over laparoscopy, particularly in patients with cirrhosis or obesity, in part from superior dexterity, optics and tremor filtration [1].

With rising rates of Obesity, MASLD and a sicker patient population, the importance of the robotic platform in maintaining superior outcomes remains paramount as it may help overcome perioperative challenges encountered in patients with these diseases. This priority is countered by a desire to cut costs [2]. Concurrently a rise in “burnout” among hospital staff threatens the viability of robotic programs, which are best served by experienced circulators and technicians who can provide bedside instrument exchange, trouble shooting and operating room turnover at optimum levels. These factors became critical during the Covid-19 pandemic and its aftermath [3]. Hospitals have responded to this crisis in healthcare staff retention by limiting robotic platform access during evenings and weekends [4].

In the context of the latter, the authors of this paper published in 2024 data demonstrating that robotic cholecystectomy remained safe and effective during after-hours, defined as an operation occurring on the weekend or evenings after 5pm [5].

Since the initial publication, our experience with urgent robotic cholecystectomy increased significantly. As of January 2026, we have accrued three years of data across multiple institutions by a single surgeon, encompassing a significantly larger cohort of patients undergoing inpatient robotic cholecystectomy for acute calculous cholecystitis during both after-hours and regular-hours periods. The objective of the current study is to update and extend our prior analysis by comparing outcomes between after-hours and regular-hours robotic cholecystectomy using this larger, multi-institutional three-year dataset. We hypothesize that robotic cholecystectomy performed after regular staffing hours remains safe and effective and that restricting access to the robotic platform based solely on time of day or week is unwarranted when procedures are performed by well-trained robotic surgeons who can guide the on-call operative team.

Methods & Materials

Inclusion Criteria

This was a single surgeon, multi-institutional retrospective study. Inclusion criteria were as follows: all patients who underwent inpatient robotic cholecystectomy for acute cholecystitis as defined by 2018 Tokyo criteria between 2021 and 2025 were included in the study. The surgeon in the study was robotic-hepatobiliary fellowship-trained who was between the “proficiency” and “plateau” phases along the robotic learning curve during this period. Exclusion criteria were as follows: any patient who underwent an operation where cholecystectomy was not the sole procedure (for example, hiatal hernia and cholecystectomy combined).

The operating surgeon does not have criteria for choosing which patient undergoes laparoscopic or robotic cholecystectomy but utilizes the platform as its availability, the needs of the patient and the schedule permits. A history of prior abdominal operations did not constitute a major contraindication to the robotic platform and it has been shown to be safe to proceed with a robotic approach in these situations.

After-hours cholecystectomy was determined if one of the following criteria was met: a) if the operation started at or after 1700 hours b) if the operation occurred on a weekend day (Saturday or Sunday). Otherwise, the case was placed in the “regular hours” cohort. No formal selection criteria were used to determine utilization of the robotic platform; access was based on robotic platform & operating room availability. Due to the retrospective nature of the study, institutional review board waiver was granted.

Patient variables

The following clinical variables were noted: age, sex, Body Mass Index (BMI), American Society of Anesthesiology (ASA) classification, a history of prior abdominal surgery and presence of cirrhosis. Preoperative laboratory values noted were: White Blood-cell Count (WBC), Neutrophil percentage, Creatinine, Glucose, Total Bilirubin (TB), Alkaline Phosphatase (AP), Aspartate aminotransferase (AST), and Alanine aminotransferase (ALT). Intraoperative variables included operative time, estimated blood loss (EBL), and total intravenous fluids (IVF) administered. Operative time was defined as the interval from initial skin incision to placement of the final dressing. Postoperative outcomes noted include conversion to open surgery, length of hospital stay (LOS), postoperative complications, 30-day readmission, and 30-day mortality. Postoperative complications were graded using the Clavien–Dindo classification system. Follow-up data were obtained through review of both inpatient and outpatient documentation.

Operative Technique

The following is the surgeon’s technique for performing robotic cholecystectomy. Patients are positioned supine on the operating table and induced with general endotracheal anesthesia. The da Vinci Xi® robotic surgical system is docked over the patient's right shoulder. The bedside assistant is the scrub technician who performs instrument changes as needed (Fig. 1). An 8 mm trocar is inserted through the umbilicus for the robotic camera by bracing technique. If no umbilical hernia is present to facilitate this, then a veress needle is introduced at palmer’s point. Three additional 8 mm robotic ports are placed under direct laparoscopic visualization; one at the right anterior-axillary line and two at the left mid-clavicular and left anterior axillary lines (Fig. 2). In the latter half of the surgeon’s experience, the left mid-clavicular 8mm trochar was upsized to a 12mm trochar. This permits introduction of pediatric lap sponges and needles. At the end of the dissection, it is slightly expanded to facilitate specimen extraction in a 10mm bag. If the umbilical hernia is significant, this is chosen for the 12mm trochar and extraction of specimen.

The following instruments are utilized from the patient’s right to left in increasing robotic arm numerical order: fenestrated bipolar, 30-degree camera, monopolar hook, small grasper. The operation begins with inspection & exposure of the porta hepatis. The falciform ligament is divided all the way to the hepatocaval confluence. This permits the small grasper to perform cephalad retraction of the liver by grasping the falciform ligament if the latter is nodular and susceptible to cracking. As a vascularized

pedicle, the mobilized falciform is also placed in the gallbladder fossa after resection to prevent a postoperative fluid collection or hematoma. The peritoneum is scored close to the infundibulum with the monopolar hook and carefully taken down. Right-angle action with the hook monopolar permits skeletonization of structures. Varicose veins encountered are destroyed with bipolar energy. Clipping of the cystic duct and artery occurs within the critical view of safety followed by division with scissors. Occasionally monopolar cautery on cut mode is utilized when scissors is not available. Indocyanine green is routinely administered in the preoperative bay to permit intraoperative fluorescent cholangiogram. The gallbladder is then removed from the liver bed with monopolar energy. In case of cirrhosis, advanced energy sealing devices are utilized for this step. The fascia is then reconstructed with slowly absorbable 0 braided suture in a figure of 8 or interrupted fashion followed by 4 – 0 absorbable monofilament suture for all skin incisions. Patients are administered a regular diet upon leaving the post-anesthesia care unit and discharged home conditionally.

Statistical Analysis

Data was collected on an Excel (Microsoft Corporation Redmond, WA) spreadsheet maintained on an encrypted portable hard drive secured within a locked office. Data was analyzed using GraphPad QuickCalcs (http://www.graphpad.com/quickcalcs/ttest1.cfm) (accessed Dec 2025) and MedCalc® Statistical Software version 23.4.8 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2026). For illustrative purposes, numerical data are presented as mean (median ± standard deviation). The following statistical tests were utilized for univariate comparisons of variables between after-hours and regular-hours cohorts: unpaired t-test for continuous variables, chi-square test for categorical variables and Mann-Whitney U test for ordinal variables. Statistical significance was determined by p-value less than 0.05. An Institutional Review Board waiver was obtained due to the retrospective nature of the study and use of deidentified patient data.

Results

A total of 161 patients met inclusion criteria. After-hours (AH) cholecystectomy occurred in 65 patients and Regular-Hours (RH) cholecystectomy occurred in 96 patients. There were no statistically significant differences between the two cohorts for Age (p = 0.208), BMI (p = 0.578), ASA (p = 0.757), Cirrhosis (p = 0.462) and Sex (p = 0.54). The AH cohort had a greater number of patients with prior abdominal operations (50.8% vs 35.4%) than the RH cohort; this difference approached statistical significance (p = 0.053) (Table 1).

In terms of preoperative laboratory values, there were no significant differences between the AH and RH cohorts for WBC count (p = 0.923), Neutrophil percentage (p = 0.592), Creatinine (p = 0.576), Total bilirubin (p = 0.109), AST (p = 0.478) and ALT (p = 0.372). There was a statistically significantly greater AP in the AH cohort vs RH cohort (88[131 ± 114] vs 124[192 ± 184] U/L, p = 0.027) (Table 2).

In terms of operative variables, there were no statistically significant differences between the AH and RH cohort in terms of operative time (p = 0.075), EBL (p = 0.428) and IVF administered (p = 0.311).

In terms of post-operative outcome variables, there were no statistically significant differences between the AH and RH cohort in terms of LOS (p = 0.818), 30-day mortality (p = 1.00), 30-day readmission rate (p = 0.624) and complications (p = 0.624) (Table 3).

On final pathology, there were no statistically significant differences between the two cohorts in terms of presence of acute cholecystitis, chronic cholecystitis nor gallbladder empyema (Table 4).

Post-operative complications were as follows: in the AH cohort, there was one CDC Class II event which was a wound hematoma managed with reversal of the patient's baseline oral anti-coagulant. There were two CDC Class III complications: one patient on immunosuppression, for a history of a kidney transplant, developed an incisional hernia requiring laparoscopic incisional hernia repair for bowel obstruction on POD 14; another patient developed a postoperative abscess requiring Interventional Radiologic (IR) drainage. In the RH cohort, there were three CDC class III complications. One patient developed a wound infection due to diet induced hyperglycemia where the patient consumed large quantities of sugar-based ice popsicles resulting in bedside incision and drainage. Two patients required endoscopic retrograde cholangiopancreatography to manage a cystic duct leak; both patients recovered uneventfully from the cystic duct leak. Both patients had monopolar cautery on cut mode utilized to cut the cystic duct between clips rather than cold scissors. One of these leaks occurred in a patient with extensive abdominal adhesions from multiple prior abdominal operations for a history of inflammatory bowel disease and was on an immunosuppressive regimen.

Discussion

This study achieved its objectives of clarifying the safety and efficacy of robotic after-hours cholecystectomy in the management of acute cholecystitis and augments the findings noted in our previous publication that robotic cholecystectomy remains safe and effective after regular staffing hours. By incorporating a larger cohort of 161 patients over an extended three-year study period operated through multiple institutions, this additional data will have greater generalizability to surgeons cultivating round-the-clock robotic platform access in the post-COVID-19 pandemic era of substantial staff burnout and turnover.

Our paper demonstrated no clinically nor statistically significant differences between the two cohorts in terms of operative time, EBL, conversion to open, complications, LOS, 30-day readmission and 30-day mortality. The fear that an urgent cholecystectomy via the robotic approach at an inconvenient hour will require an excessive amount of time appears to be unjustified.

To attenuate confounding factors, baseline laboratory and clinical variables between the two cohorts were analyzed; no clinically significant differences were noted. In fact, the AH group had a clinically but not quite statistically significantly greater number of patients with prior abdominal operations, just as in

our 2024 study, demonstrating once more that the robotic platform can equalize technical challenges involving difficult or altered anatomy – as has been demonstrated in more challenging Hepatopancreaticobiliary operations [6, 7].

As noted in many other studies, the robotic platform offers enhanced dexterity over both human hands but more importantly over straight stick laparoscopy. Manipulation of an inflamed and intrahepatic gallbladder is particularly challenging when the working end of an instrument cannot be angled around corners. Even with a 30-degree laparoscope, visualization can be challenging. A three-dimensional camera can allow for a superior image, while tremor filtration ensures precise but thoughtful ergonomics.

The AH group did have a statistically significantly lower AP lab level, but the difference in median value was only 36 IU/L. The clinical significance of the latter can be confidently demoted by the statistically and clinically insignificant differences in other liver function tests, particularly total bilirubin level.

More to the point of the paper, round-the-clock access to the robotic platform for acute cholecystitis should not be hindered. Even in an era of increasing staff burnout and turnover, an experienced robotic surgeon can effectively guide the operating room team which may have variable levels of familiarity with the platform, coordinating tasks such as instrument exchange, suction, retraction, and maintenance of the sterile field. This guidance appears to preserve procedural efficiency and safety even in after-hours conditions with limited or variable staffing.

The importance of this topic lies in the ongoing need to improve outcomes as our patient population remains unhealthy, if not unhealthier, then ever before. Patients with obesity are difficult to perform laparoscopy upon because the thick abdominal wall strains a surgeon's arms during an operation. Greater strength applied to move against the abdominal wall limits the ability to perform fine dissection. The greater visceral fat also reduces operating space. The robotic platform may nullify these technical challenges and with efficient surgeon-guided docking, the operation may be quicker, something of great importance when patients with congestive heart failure cannot tolerate prolonged anesthetic or pneumoperitoneum.

Perhaps the most important aspect of this study lies in its context; most recently, *Zhi Ven Fong et al* published findings that correlated access to the robotic platform with a decrease in rate of "open" operations [8]. Therefore, the importance of round-the-clock access to the robotic platform cannot be stressed enough in improving the quality of care afforded to patients, who clearly do better in avoiding an "open" scar that is more disfiguring, painful and prone to infection [9].

Since the submission of our initial findings in late 2023, a similar study was published demonstrating similar findings. *Choudry et al* included 505 patients undergoing robotic cholecystectomy for various reasons, including 160 AH cholecystectomies [10]. The study was also performed over multiple institutions but with multiple surgeons. Unlike our study, they did not control for disease severity with 2018 Tokyo criteria. They found that due to the acute nature of patients who presented during "after-

hours", cases in this cohort had a greater operative time, but also a lesser risk of conversion to open and length of stay compared to regular-hours (what they called "business hours") cholecystectomy. Regardless, their larger multi-surgeon paper showed AH robotic cholecystectomy to be safe and effective. Together, their paper and this one compliments and validates the importance of maintaining round-the-clock access to robotic technology in the management of acute cholecystitis.

This study has a few limitations. The author recognizes that there are differences in institutional protocols, staffing patterns, and perioperative management which may introduce variability that could affect outcomes and generalizability to surgeons in other hospitals. By utilizing a broad dataset from multiple institutions across a few years, it was hoped this institutional variability would be diluted, since both AH and RH cases occurred at multiple locations. Additionally, while the study includes a larger cohort than prior analyses, the number of after-hours cases may be insufficient to detect very rare complications, such as bile duct injury or major hemorrhage – neither of which occurred in this study. Lastly, potential selection bias exists, as patients presenting after-hours may differ in unmeasured ways from those who present during regular hours; it is the authors opinion that patients who wish to avoid losing work present during "after-hours" where else patients who do not present at any time. This may introduce a level of bias almost impossible to control for, but it reflects the reality of the overall patient population as well, who may access hospital care based on convenience rather than severity.

Future investigations should evaluate the applicability of these findings to other robotic procedures, higher-complexity cases, and more diverse patient populations. Assessing long-term outcomes, patient-reported metrics, and cost-effectiveness is important, but the difficulty in reliably measuring these elusive variables remains challenging particularly in regards to the latter.

Conclusion

Robotic cholecystectomy for acute cholecystitis performed "after-hours" can occur safely and effectively. This 3-year follow up study from our prior publication strengthens its prior findings with significantly more cases. A well-trained robotic surgeon can guide on-call operating room staff to an efficient procedure during evenings and weekends. This was demonstrated in robotic cholecystectomy; investigating the application of this platform in other specialties and operations can allow for greater extrapolation of our findings and advocate for greater robotic platform accessibility. We hope this will translate to better equipped surgeons and better treated patients.

Declarations

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Author Contribution

All authors contributed to the concept, design, data acquisition, composition, analysis, proof-reading and final acceptance of this manuscript.

Data Availability

Data available upon request.

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Tables

Table 1
– Preoperative Demographic Variables

Patients (n)	After-Hours	Regular-Hours	Total| p-Value
	65	**96**	
Age (years)	57 (54 ± 18)	61 (57 ± 18)	0.208
Sex (M/F)	20/45	34/62	0.540
BMI (kg/m2)	31 (31 ± 6.5)	30 (30 ± 6.7)	0.578
ASA (1–6)	3 (3 ± 1)	3 (3 ± 1)	0.757
Prior Abdominal Procedure (n)	33	34	0.053
Cirrhosis (n)	4	9	0.462

Table 2
– Preoperative Laboratory Variables

Patients (n)	After-Hours	Regular-Hours	Total| p-Value
	65	**96**	**161**
WBC (x 10^3.μL^{-1})	8.8 (10 ± 5.5)	8.9 (10 ± 5.6)	0.923
Neutrophil Percentage (%)	70 (71 ± 18)	73 (72 ± 29)	0.592
Glucose (mg.dL^{-1})	115 (146 ± 79)	111 (126 ± 54)	0.058
Creatinine (mg.dL^{-1})	0.8 (1.1 ± 0.9)	0.9 (1.0 ± 0.7)	0.576
Alanine Transaminase (IU.dL^{-1})	35 (129 ± 188)	80 (160 ± 196)	0.372
Aspartate Transaminase (IU.dL^{-1})	26 (99 ± 186)	65 (120 ± 149)	0.478
Alkaline Phosphatase (IU.dL^{-1})	88 (131 ± 114)	124 (192 ± 184)	**0.027**
Total Bilirubin (mg.dL^{-1})	0.8 (1.5 ± 2.3)	1.2 (2.1 ± 2.1)	0.109
Values listed as median ± standard deviation where applicable			

Table 3
– Postoperative Variables

Patients (n)	After-Hours	Regular-Hours	Total| p-Value
	65	**96**	**161**
Operative Time (min)	70 (69 ± 27)	67 (79 ± 40)	0.075
Estimated Blood Loss (ml)	25 (43 ± 75)	18 (53 ± 84)	0.428
Intravenous Fluids (IVF) Given (ml)	1000 (935 ± 359)	1000 (1015 ± 555)	0.311
Conversion to 'open'	0	0	N/A
Length of Stay (days)	1.0 (1.8 ± 1.6)	1.0 (1.7 ± 2.1)	0.818
Complications	3 (II, III, III)	3 (III, III, III)	0.624
30-day Readmission	3/65	3/96	0.624
30-day Mortality	0	0	N/A
Values listed as median ± standard deviation where applicable			

Table 4
– Pathology

Acute Cholecystitis	After hours	Regular hours	p-value
	38/65	**49/96**	**0.354**
Chronic Cholecystitis	65/65	94/96	0.242
Necrotizing / Empyema Cholecystitis	10/65	14/96	0.889

Figures

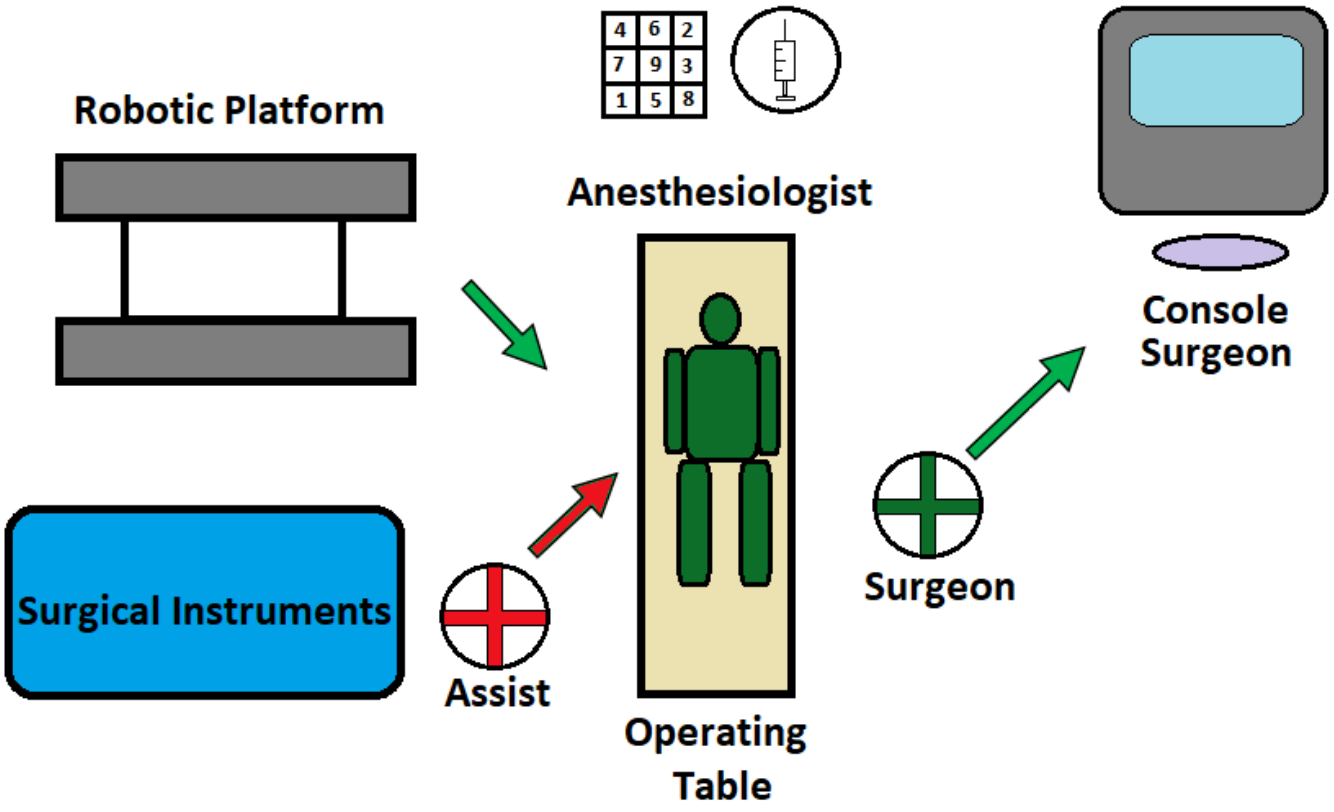


Figure 1

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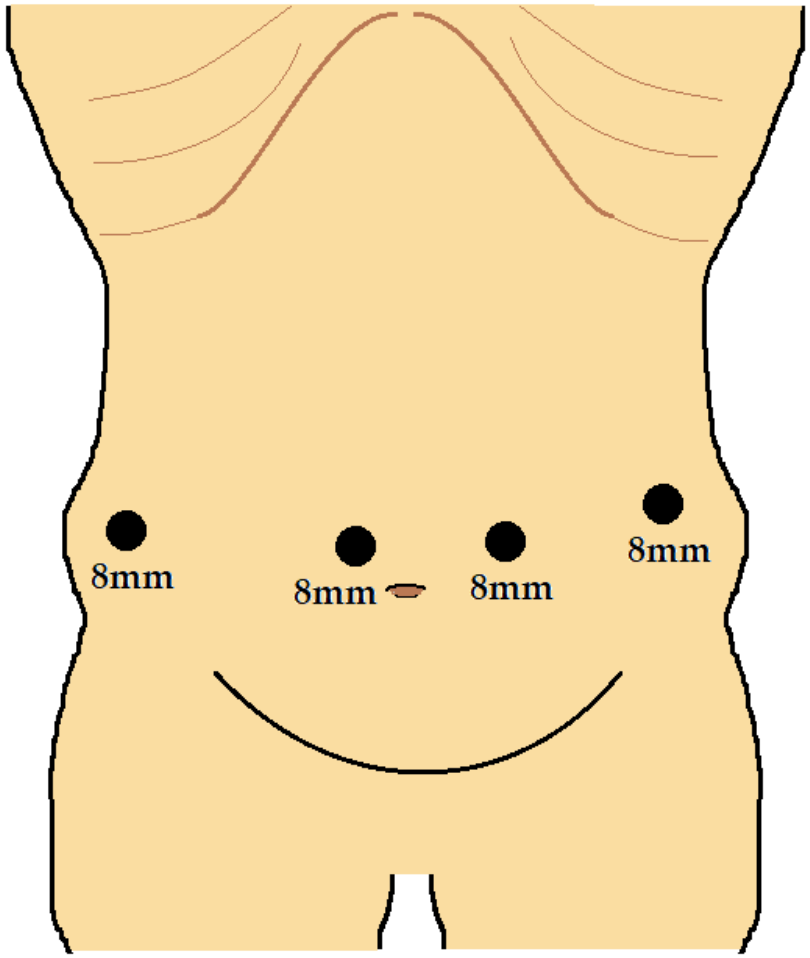


Figure 2

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Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1PreoperativeDemographicVariables.docx
- Table4Pathology.docx
- Table2PreoperativeLaboratoryVariables.docx
- Table3PostoperativeVariables.docx