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Original Article

Use of Methylene Blue Dye During Laparoscopic Cholecystectomy for Mapping of Extrahepatic Biliary Tree

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ABSTRACT

Background: Laparoscopic cholecystectomy is the standard surgical treatment for symptomatic gallstone disease; however, bile duct injury remains one of the most serious complications. Accurate identification of extrahepatic biliary anatomy is essential for safe surgery. Intraoperative methylene blue dye injection has been proposed as a simple technique to improve visualization of biliary structures. **Objective:** This study aimed to evaluate the efficacy and safety of methylene blue dye use during laparoscopic cholecystectomy for delineation of extrahepatic biliary tree. **Methods & Materials:** This quasi-experimental study was conducted in the Department of Surgery, Chattogram Medical College Hospital, over a 12-month period from February 2022 to January 2023. A total of 111 patients with symptomatic gallstone disease undergoing laparoscopic cholecystectomy were included using convenient sampling. Diluted methylene blue dye was injected intraoperatively into the gallbladder lumen for visualization of biliary anatomy. Patients were followed postoperatively to assess complications. Statistical analysis was performed using SPSS version 25. **Results:** Mean age of patients was 42.8±12.3 years and 76.6% were female. Chronic cholecystitis was the most common clinical presentation (86.5%). Gallbladder visualization was achieved in 91.0% of cases, cystic duct in 73.0% and common bile duct in 27.0%. Mean operative time was 49.98±11.94 minutes. Postoperative urine discoloration occurred in 7.2% of patients. Mean hospital stay was 1.18±0.39 days. **Conclusion:** Intraoperative methylene blue dye injection is a feasible, safe and cost-effective method for delineation of extrahepatic biliary anatomy during laparoscopic cholecystectomy. The technique may reduce the risk of bile duct injury and can be useful in settings where advanced imaging modalities are not available.

Keywords: *Laparoscopic cholecystectomy, methylene blue dye, bile duct injury, gallstone disease, extrahepatic biliary tree.*

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INTRODUCTION

Gallstone disease is one of the most common gastrointestinal disorders worldwide, with an estimated prevalence ranging from 10–20% in developed countries [1]. Cholecystectomy remains the standard treatment for symptomatic gallstone disease, and laparoscopic cholecystectomy (LC) has become the gold standard surgical procedure since the early 1990s due to its advantages of reduced postoperative pain, shorter hospital stays, faster recovery and improved cosmetic outcomes [2,3]. Currently, more than 90% of cholecystectomies are performed laparoscopically, reflecting the widespread acceptance of this minimally invasive approach [4].

Despite its benefits, laparoscopic cholecystectomy is associated with specific complications, among which bile duct injury (BDI) is considered the most serious and potentially life-threatening. BDI may lead to significant morbidity, prolonged hospitalization, repeated surgical interventions and increased healthcare costs [5,6]. The incidence of bile duct injury during LC has been reported to range from 0.2% to 0.5%, which is approximately two times higher compared to open cholecystectomy [7,8]. Misinterpretation of biliary anatomy is considered the most common cause of these injuries, occurring in up to 97% of cases [9]. Factors contributing to anatomical misidentification include inflammation, adhesions, anatomical variation, surgeon experience and technical limitations during surgery [10,11].

Accurate identification of the extrahepatic biliary tree is therefore crucial for safe laparoscopic cholecystectomy. Various techniques have been developed to improve visualization of biliary anatomy, including intraoperative cholangiography (IOC), laparoscopic ultrasound (LUS) and near-infrared fluorescent cholangiography (NIRFC). However, these techniques have limitations such as increased operative time, requirement of specialized equipment, radiation exposure, high cost and operator dependency [12,13].

Methylene blue dye has been proposed as an alternative technique for intraoperative delineation of biliary anatomy. The dye is injected into the gallbladder lumen to provide direct visualization of the cystic duct and common bile duct during dissection of Calot's triangle. This method is relatively simple, inexpensive and does not require sophisticated equipment or radiation exposure. Previous studies have demonstrated that methylene blue injection may improve visualization of biliary structures and reduce the risk of bile duct injury during laparoscopic cholecystectomy [14,15].

Methylene blue has a long history of safe clinical use and is widely available, making it particularly suitable in resource-limited settings. The technique may be especially beneficial for surgeons during the early learning curve or in cases of difficult cholecystectomy where anatomical identification becomes challenging [16].

However, evidence regarding the effectiveness of methylene blue dye for mapping the extrahepatic biliary tree

remains limited, particularly in developing countries. Therefore, this study was conducted to evaluate the efficacy and safety of intraoperative methylene blue dye injection during laparoscopic cholecystectomy for delineation of extrahepatic biliary anatomy and prevention of biliary injury.

OBJECTIVES

The objective of the study was to evaluate the efficacy and safety of intraoperative methylene blue dye injection for delineation of the extrahepatic biliary tree, including the cystic duct and common bile duct, in order to minimize biliary injury during laparoscopic cholecystectomy.

METHODS & MATERIALS

This quasi-experimental study was conducted in the Department of Surgery at Chattogram Medical College Hospital, Chattogram, Bangladesh, over a 12-month period from February 2022 to January 2023. The study population consisted of patients diagnosed with symptomatic gallstone disease who underwent laparoscopic cholecystectomy (LC). A total of 111 patients were selected using a convenient sampling technique according to predefined eligibility criteria.

Inclusion criteria

1. Patients with symptomatic gallstone disease, including complicated gallstone disease such as acute cholecystitis, mucocele of gallbladder and empyema gallbladder
2. Patients aged 18–70 years
3. Patients willing to participate in the study

Exclusion criteria

1. Excessively fibrosed or contracted gallbladder where needle insertion into the lumen was not feasible
2. Patients with choledocholithiasis
3. Patients with impaired renal function (serum creatinine >2 mg/dl)
4. Patients with uncontrolled comorbid conditions
5. Patients unwilling to participate

Data Collection Procedure

Patients fulfilling eligibility criteria were enrolled after obtaining written informed consent. Detailed clinical history, physical examination and relevant investigations were performed prior to surgery. All patients underwent laparoscopic cholecystectomy under general anesthesia using standard four-port technique. After exposure of the gallbladder fundus, bile was aspirated using a laparoscopic needle, followed by slow injection of 50% diluted methylene blue dye equal to the aspirated bile volume into the gallbladder lumen. The puncture site was secured to prevent dye leakage. After dye injection, delineation of the gallbladder, cystic duct and common bile duct was visualized intraoperatively, and dissection of Calot's triangle was performed accordingly. Postoperative follow-up was conducted at 24 hours, 7 days and 14 days to identify complications. Data were recorded using a structured case record form.

Ethical Considerations

Ethical approval was obtained from the Department of Surgery and relevant institutional authority of Chattogram Medical College Hospital. Participation was voluntary and informed consent was obtained after explaining study objectives and procedures in understandable language. Confidentiality of patient information was strictly maintained and data were used solely for research purposes. Patients were informed about potential harmless discoloration of urine following methylene blue administration.

Statistical Analysis

Collected data were processed and analyzed using Statistical Package for Social Sciences (SPSS) version 25. Quantitative variables were expressed as mean ± standard deviation, while categorical variables were presented as frequency and percentage. Chi-square test was applied to determine associations between categorical variables. Statistical significance was considered at $p < 0.05$ with 95% confidence interval. Data were presented using tables and figures where appropriate.

RESULT

Table I shows that the mean age of the study patients was 42.8±12.3 years, with the majority belonging to the 31–40 years age group. Female patients constituted 76.6% of the study population. Most participants were overweight (54.1%).

Table I
Baseline Demographic and Clinical Characteristics (*n* = 111).

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	≤20	1	0.9
	21–30	18	16.2
	31–40	35	31.5
	41–50	29	26.1
	51–60	16	14.4
	>60	12	10.8
	Mean age ± SD	42.8 ± 12.3	
Gender	Male	26	23.4
	Female	85	76.6
BMI (kg/m²)	Normal	43	38.7
	Overweight	60	54.1
	Obese	8	7.2

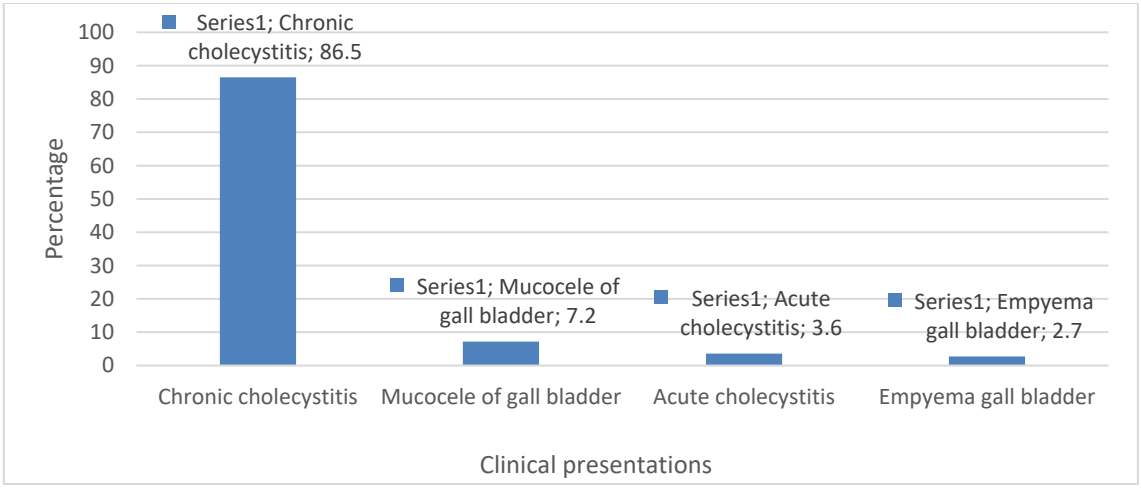

Figure 1 Distribution of the study patients according to clinical presentations (*n*=111).

Regarding clinical presentations, chronic cholecystitis was found in 96(86.5%), mucocele of gall bladder 8(7.2%), acute cholecystitis 4(3.6%) and empyema gall bladder 3(2.7%) *Figure 1*.

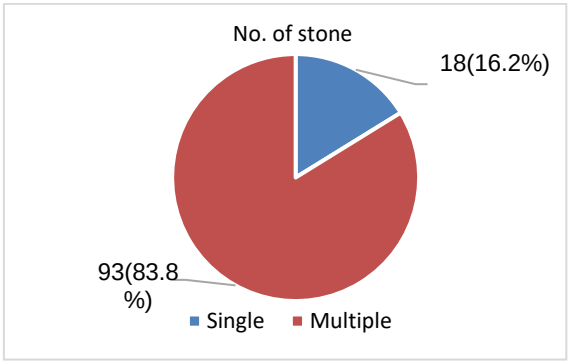

Figure 2 Distribution of the study patients according to no. of stone (*n*=111).

Figure 2 shows that majority 93(83.8%) patients had multiple stone and 18(16.2%) had single stone.

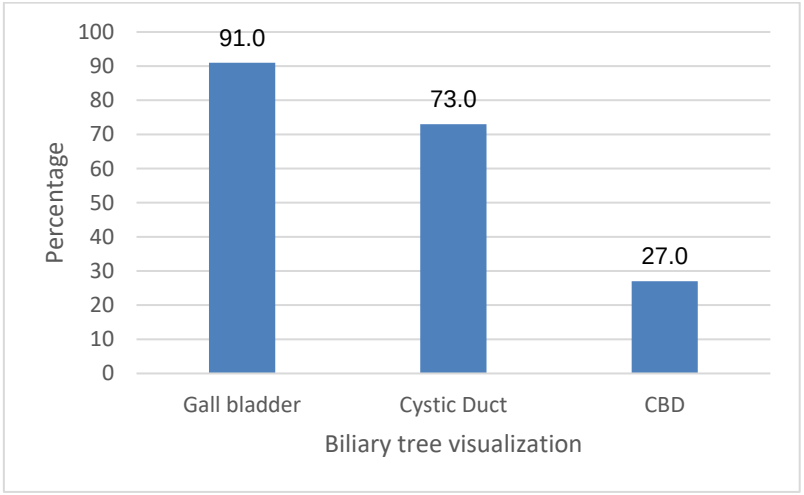

Figure 3 Distribution of the study patients according to biliary tree visualization (*n*=111)

By using Methylene Blue Dye technique 101 gall bladders were colored, while 81 cystic ducts were colored (73.0%) and common bile ducts (CBD) were colored in 30 patients (27.0%). *Table II* shows that mean operative time was 49.98±11.94 minutes with range of operative time was 30 to 87 minutes.

Table II
Distribution of the study patients according to operative time (*n*=111).

Variable	Mean±SD	Range
Operative time (minutes)	49.98±11.94	30–87

Table III shows that 8 (7.2%) patients developed urine discoloration following the procedure.

Table III
Distribution of the study patients according to postoperative complications (*n*=111)

Postoperative complications	Frequency	Percentage
Urine discoloration	8	7.2

Table IV shows the pattern of biliary tree visualization according to gallbladder pathology. No statistically significant association was observed.

Table IV
Pattern of successful painting versus different gallbladder status.

Clinical presentation	Total	Gall bladder n (%)	Cystic duct n (%)	CBD n (%)	P value
Chronic cholecystitis	96	87 (90.6)	72 (75.0)	28 (29.2)	0.546
Mucocele	8	7 (87.5)	4 (50.0)	1 (12.5)	0.709
Acute cholecystitis	4	4 (100.0)	4 (100.0)	1 (25.0)	0.915
Empyema	3	3 (100.0)	1 (33.3)	0 (0.0)	0.496

Table V shows no statistically significant association between number of stones and successful biliary tree visualization.

Table V
Pattern of successful painting versus number of stone.

Number of stones	Total	Gall bladder n (%)	Cystic duct n (%)	CBD n (%)	P value
Single	18	16 (88.9)	14 (77.8)	7 (38.9)	0.636
Multiple	93	85 (91.4)	67 (72.0)	23 (24.7)	

Table VI shows that mean hospital stay was 1.18±0.39 days.

Table VI
Distribution of the study patients according to hospital stay (*n*=111).

Variable	Mean±SD	Range
Hospital stay (days)	1.18±0.39	1–2

DISCUSSION

The present quasi-experimental study evaluated the efficacy and safety of intraoperative methylene blue (MB) dye injection during laparoscopic cholecystectomy for delineation of the extrahepatic biliary tree. A total of 111 patients undergoing laparoscopic cholecystectomy for symptomatic gallstone disease were included over one year. The findings of the present study were compared with previously published literature to assess consistency and clinical relevance.

In the present study, the mean age of patients was 42.8±12.3 years, with the majority of patients belonging to the 31–40 year age group. A similar age distribution was reported by Al-Najafi et al., who observed a mean age of 44 years among patients undergoing laparoscopic cholecystectomy [17]. Comparable findings were also described by de Reuver et al., who reported a mean age of 48.2±15 years [18]. Abdelaziz reported a mean age of 34.6±13.74 years [15], while Hassan et al. also documented a similar age range among study participants [14]. Differences in mean age across studies may be attributed to geographical variation, dietary habits, genetic predisposition and healthcare accessibility.

Female predominance was observed in the present study, where 76.6% of patients were female, consistent with previous studies demonstrating a higher prevalence of gallstone disease among females. Abd Al-Helfy reported that 73.5% of patients undergoing laparoscopic cholecystectomy were female, while Al-Najafi et al. reported 77.5% female patients [16,17]. Hassan et al. observed an even higher proportion of female patients (90%), supporting the established association between female gender and gallstone disease [14]. Hormonal influences, particularly estrogen-related cholesterol supersaturation of bile, may contribute to this higher prevalence in females.

In the present study, chronic cholecystitis was the most common clinical presentation (86.5%), followed by mucocele of the gallbladder and acute cholecystitis. Multiple gallstones were present in 83.8% of patients. Similar patterns of clinical presentation were reported in earlier studies where chronic calculous cholecystitis constituted the majority of cases undergoing laparoscopic cholecystectomy. Chronic inflammation may lead to distortion of anatomy and increase the difficulty of identification of biliary structures during surgery, thereby increasing the risk of bile duct injury.

In this study, methylene blue dye injection enabled visualization of the gallbladder in 91% of cases, cystic duct in 73% of cases and common bile duct (CBD) in 27% of cases. Comparable findings were reported by Hassan et al., who demonstrated successful delineation of gallbladder, cystic duct and CBD in most patients using the methylene blue injection technique [14]. Abdelaziz reported cystic duct visualization in 93% of cases and CBD visualization in 63% of cases. Differences in visualization rates may be attributed to variation in gallbladder wall thickness, severity of

inflammation, injection technique and surgeon experience [15].

The lower visualization rate of CBD observed in this study (27%) may be explained by fibrosis, thickened gallbladder wall and obstruction caused by impacted stones. Previous studies have also suggested that thick-walled gallbladders may reduce effective dye distribution into the biliary tree. Abd Al-Helfy reported reduced coloration of the cystic duct and CBD in complicated gallstone disease compared with uncomplicated cases [16]. These findings suggest that methylene blue injection may be more effective in early disease stages where anatomical distortion is minimal.

The mean operative time observed in the present study was 49.98±11.94 minutes, which is comparable to or shorter than operative durations reported in previous studies. Hassan et al. reported a mean operative time of 78.63±12.37 minutes, while Abd Al-Helfy reported a mean operative time of 55 minutes [16]. Rabie also reported shorter operative duration in patients undergoing methylene blue assisted laparoscopic cholecystectomy compared to the conventional technique [19]. These findings indicate that methylene blue injection does not significantly prolong operative duration and may facilitate safer dissection of Calot's triangle.

Postoperative complications were minimal in this study, with urine discoloration observed in 7.2% of patients. This finding is consistent with the pharmacological profile of methylene blue, which is excreted through urine after systemic absorption. Previous studies have also reported transient urine discoloration as a benign and self-limiting side effect of methylene blue injection. No major complications such as bile duct injury or biliary leakage were observed, supporting the safety of this technique.

Mean hospital stay in this study was 1.18±0.39 days, which is comparable to findings reported by Abd Al-Helfy and Rabie, who reported mean hospital stays ranging from 1 to 2 days [16,19]. Short duration of hospitalization reflects the minimally invasive nature of laparoscopic cholecystectomy and suggests that methylene blue injection does not increase postoperative morbidity.

Various alternative techniques, such as intraoperative cholangiography, laparoscopic ultrasound, and near-infrared fluorescence cholangiography, have been proposed for the intraoperative identification of biliary anatomy. However, these techniques require specialized equipment, increase procedural cost and may prolong operative time. In contrast, methylene blue dye is inexpensive, easily available and technically simple to perform. Previous literature suggests that intraoperative dye techniques may reduce bile duct injury by improving visualization of biliary anatomy during dissection.

Overall, the findings of the present study suggest that intraoperative methylene blue injection is a feasible and safe technique for delineation of extrahepatic biliary anatomy during laparoscopic cholecystectomy. The technique may be particularly useful in resource-limited settings where advanced imaging modalities are not readily available. Although the CBD visualization rate was relatively lower, the technique demonstrated satisfactory delineation of gallbladder and cystic duct in the majority of cases, supporting its potential role as an adjunct method for the prevention of bile duct injury.

CONCLUSION

The present study demonstrates that intraoperative methylene blue dye injection during laparoscopic cholecystectomy is a simple, safe and cost-effective technique for delineation of extrahepatic biliary anatomy. The technique showed high visualization rate of gallbladder and cystic duct with minimal complications and short hospital stay. Although visualization of the common bile duct was relatively lower, methylene blue dye may serve as a useful adjunct method for reducing biliary injury, particularly in resource-limited surgical settings.

CONFLICTS OF INTEREST

There are no conflicts of interest.

ETHICAL APPROVAL

This study approved by the institutional ethical review committee.

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