Barind Medical College Journal
Abbreviated Key Title: BMCJ
ISSN: 2518-3249 (Print)
https://bmcj.org/index.php/bmcj
Volume-10 | Issue-1 | Jan-Jun, 2024 | DOI: https://doi.org/10.70818/bmcj.2024.v010i01.005

OPEN ACCESS

Original Research Article

Impact of Indocyanine Green Fluoroscopy on Bile Duct Identification during Laparoscopic Cholecystectomy: A 40-Patient Observational Analysis

Dr. Anharur Rahman[a]*, Dr. Anas Ahmed[b], Dr. Ahmed-Al-Hasan Mahmud[c],

[a]Associate Professor (Surgery), Z.H.Sikder women's Medical College & Hospital
[a]Consultant (General & Hepatobiliary pancreatic Surgery, Central Hospital Ltd.
[a]Lab aid cancer Hospital & Superspeciality center, Dhaka

[b]Specialist (Surgery), Sheikh Fazilatunnesa Mujib Memorial KPJ Specialized Hospital & Nursing College, Gazipur

[c]Specialist and Coordinator (Surgical Oncology), LabAid Cancer Hospital & Superspeciality Centre, Dhaka

***Correspondence to:**

Dr. Anharur Rahman
Associate Professor (Surgery), Z.H.Sikder women's Medical College & Hospital & Consultant (General & Hepatobiliary pancreatic Surgery, Central Hospital Ltd. Labaid Cancer Hospital and Super Speciality Centre, Dhaka
Email: anhar92@gmail.com

Article History
Received: 12.03.2024
Accepted: 23.05.2024
Published: 30.06.2024

Abstract: ***Background*:** Laparoscopic cholecystectomy (LC) is a prevalent surgical procedure with inherent risks, notably bile duct injuries (BDIs). ***Objective:*** This study aims to evaluate the efficacy of Indocyanine Green (ICG) fluoroscopy in enhancing bile duct identification during LC. ***Methods:*** A prospective cohort of 40 patients undergoing LC at Central Hospital Ltd, and Labaid Cancer Hospital and Super Speciality Centre, Dhaka, Bangladesh (2022-2023) was analyzed. Patients received an intravenous dose of ICG (0.5 mg/kg) intraoperatively. Near-infrared fluorescence imaging was employed to visualize biliary structures. Identification rates of bile ducts with and without ICG fluoroscopy were compared using statistical analysis ($p < 0.05$). ***Results:*** ICG fluoroscopy significantly improved bile duct identification, achieving a 95% success rate compared to 72% without ICG ($p = 0.003$). This represents a 31% relative increase in identification accuracy. The mean operative time was reduced by 15 minutes in the ICG group (mean 92 minutes, SD ±10, range 65-125 minutes). Demographically, 60% were male and 40% female, with a mean age of 37.26 years (SD ±8.5). Additionally, the use of ICG fluoroscopy was associated with a 50% reduction in intraoperative complications related to bile duct misidentification. No adverse events attributable to ICG administration were observed, ensuring its safety profile. The enhanced visualization facilitated clearer delineation of the cystic duct and common bile duct, contributing to improved surgical precision and outcomes. Statistical analysis confirmed the significance of these findings, with confidence intervals for identification rates ranging from 20% to 42%. **Conclusions:** The integration of ICG fluoroscopy in LC markedly enhances bile duct identification, thereby reducing the incidence of BDIs and improving surgical outcomes. These findings support the routine use of ICG fluoroscopy to enhance patient safety during laparoscopic cholecystectomy.

Keywords: Indocyanine Green, Fluoroscopy, Laparoscopic Cholecystectomy, Bile Duct Identification, Patient Safety.

Cite this as: Rahman A, Ahmed A, Mahmud AA. Impact of indocyanine green fluoroscopy on bile duct identification during laparoscopic cholecystectomy: a 40-patient observational analysis. BMCJ. 2024;10(1):4-14.

Introduction

Laparoscopic cholecystectomy (LC) has become the gold standard for the surgical management of benign gallbladder diseases, primarily due to its minimally invasive nature, reduced postoperative pain, shorter hospital stays, and accelerated return to normal activities compared to open cholecystectomy.[1] Despite its widespread adoption and numerous benefits, LC is not devoid of complications, with bile duct injury (BDI) being one of the most significant and concerning. BDI, although relatively rare with an incidence ranging from 0.3% to 0.7%, can lead to severe morbidity, extended hospitalization, increased healthcare costs, and, in some cases, mortality.[2] The complexity of the biliary anatomy, variations such as the "hidden cystic duct," and the challenges inherent to the laparoscopic approach contribute to the risk of inadvertent injury to the common bile duct (CBD) or other biliary structures.[3]

Traditional methods for identifying and delineating the biliary anatomy during LC include the use of intraoperative cholangiography (IOC) and meticulous dissection techniques. However, these methods have limitations. IOC, while effective in visualizing the biliary tree, is technically demanding, time-consuming, and exposes both patients and surgical staff to radiation. Moreover, its routine use remains controversial, with some studies advocating selective application based on intraoperative findings rather than as a standard procedure.[4] In recent years, the advent of fluorescence imaging technology, particularly the utilization of Indocyanine Green (ICG) fluoroscopy, has emerged as a promising adjunct in enhancing bile duct identification during LC. ICG is a water-soluble, tricarbocyanine dye that, when administered intravenously, is rapidly taken up by the liver and excreted exclusively into the bile without being metabolized.[5] Its near-infrared fluorescence properties enable real-time, high-contrast imaging of biliary structures when coupled with appropriate imaging systems. This modality offers several advantages over traditional techniques, including ease of use, absence of ionizing radiation, and the ability to provide continuous visualization without the need for additional procedures.

Several studies have demonstrated the efficacy of ICG fluoroscopy in improving the visualization of the biliary anatomy during LC. For instance, a randomized controlled trial by similar study reported that the use of ICG fluorescence significantly reduced the incidence of BDI compared to standard LC. Similarly, research by Serban *et al.* indicated that ICG-guided LC facilitated clearer identification of the cystic duct and CBD, thereby enhancing surgical safety and efficiency.[6] These findings underscore the potential of ICG fluoroscopy as a valuable tool in minimizing BDI rates and improving surgical outcomes. However, despite the promising evidence, the integration of ICG fluoroscopy into routine surgical practice remains variable, influenced by factors such as the availability of fluoroscopic equipment, surgeon familiarity with the technology, and institutional protocols.[7] Additionally, while existing studies have largely focused on the efficacy of ICG in reducing BDI rates, there is a paucity of data from observational analyses that assess its impact in real-world clinical settings, particularly in diverse patient populations and varying surgical contexts.

The present study aims to address this gap by conducting an observational analysis of 40 patients undergoing LC with the assistance of ICG fluoroscopy for bile duct identification. By systematically evaluating the outcomes, including the accuracy of bile duct visualization, incidence of BDI, operative time, and overall surgical success, this research seeks to provide a comprehensive assessment of the practical utility and effectiveness of ICG fluoroscopy in enhancing the safety and precision of LC. Furthermore, this study endeavors to contribute to the body of evidence supporting the routine adoption of fluorescence-guided techniques in laparoscopic surgery, potentially influencing surgical guidelines and standard care practices. Understanding the impact of ICG fluoroscopy on bile duct identification is crucial, not only for improving individual patient outcomes but also for informing surgical training and the allocation of resources within healthcare systems. As surgical technology continues to evolve, the integration of advanced imaging modalities like ICG fluoroscopy represents a pivotal advancement in laparoscopic surgery, aligning with the broader

objectives of precision medicine and patient-centered care. By elucidating the benefits and limitations of ICG-assisted LC, this research aspires to foster evidence-based enhancements in surgical protocols, ultimately contributing to the reduction of surgical complications and the advancement of minimally invasive surgical techniques.

Aims and Objective

This study aims to rigorously assess the effectiveness of Indocyanine Green (ICG) fluoroscopy in enhancing bile duct identification during laparoscopic cholecystectomy. Specifically, it seeks to quantify the improvement in identification rates, evaluate the reduction in bile duct injuries, and determine the overall impact on surgical outcomes and operative efficiency in a cohort of 40 patients.

Materials and methods

Study Design

This prospective observational study was conducted to evaluate the impact of Indocyanine Green (ICG) fluoroscopy on bile duct identification during laparoscopic cholecystectomy (LC). Conducted at Central Hospital Ltd, and Labaid Cancer Hospital and Super Speciality Centre in Dhaka, Bangladesh, the study spanned from January 2022 to December 2023. A cohort of 40 patients undergoing LC was meticulously followed to assess the efficacy and safety of ICG-assisted visualization techniques in a real-world clinical setting.

Inclusion Criteria

Participants eligible for this study were adults aged 18 years and older diagnosed with benign gallbladder diseases requiring laparoscopic cholecystectomy. Patients scheduled for elective LC, regardless of gender, were included provided they provided informed consent. Additionally, individuals with a body mass index (BMI) between 18.5 and 35 kg/m² and no history of previous biliary surgery or known biliary anatomical anomalies were considered. Patients with indications for urgent or emergency surgery were excluded to maintain consistency in the surgical approach and outcomes.

Exclusion Criteria

Patients were excluded from the study if they had a history of allergic reactions to indocyanine green or iodine-based contrast agents. Additionally, individuals with significant hepatic dysfunction, renal impairment, or those on medications that could interfere with ICG metabolism were not included. Pregnant or breastfeeding women were excluded to avoid potential risks associated with ICG administration. Furthermore, patients with acute cholecystitis, pancreatitis, or those requiring conversion to open surgery were omitted to ensure the homogeneity of the laparoscopic procedure outcomes.

Data Collection

Data were systematically collected through patient medical records, operative reports, and postoperative assessments. Preoperative information included demographic details, medical history, and laboratory parameters. Intraoperative data encompassed the administration dosage of ICG, operative time, and the success rate of bile duct identification with and without ICG fluoroscopy. Postoperative outcomes focused on the incidence of bile duct injuries, any adverse reactions to ICG, and overall surgical success. All data were recorded using a standardized case report form to ensure consistency and accuracy across the study.

Data Analysis

Data were analyzed using SPSS version 26.0. Descriptive statistics were employed to summarize demographic and clinical characteristics, including means, standard deviations, and percentages. Comparative analyses between the ICG-assisted group and the non-ICG group were performed using the Chi-square test for categorical variables and t-test for continuous variables. The primary outcome, bile duct identification rate, was evaluated for statistical significance with a p-value threshold set at <0.05. Additionally, confidence intervals were calculated to assess the precision of the observed differences. Logistic regression analysis was conducted to adjust for potential confounders and to determine the independent effect of ICG fluoroscopy on bile duct identification.

Ethical Considerations

This study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the Institutional Review Board of Z.H. Sikder Women's Medical College Hospital and Central Hospital Ltd, and Labaid Cancer Hospital and Super Speciality Centre, Dhaka, Bangladesh. Informed consent was obtained from all participants prior to inclusion in the study. Confidentiality of patient information was strictly maintained, and all data were anonymized to protect patient privacy. The study protocol ensured that participation was voluntary, with the right to withdraw at any stage without affecting the standard of care. Additionally, the potential risks and benefits of ICG fluoroscopy were clearly communicated to all participants.

Figure 1: ICG 4K camera system doing Complicated Laparoscopic cholecystectomy

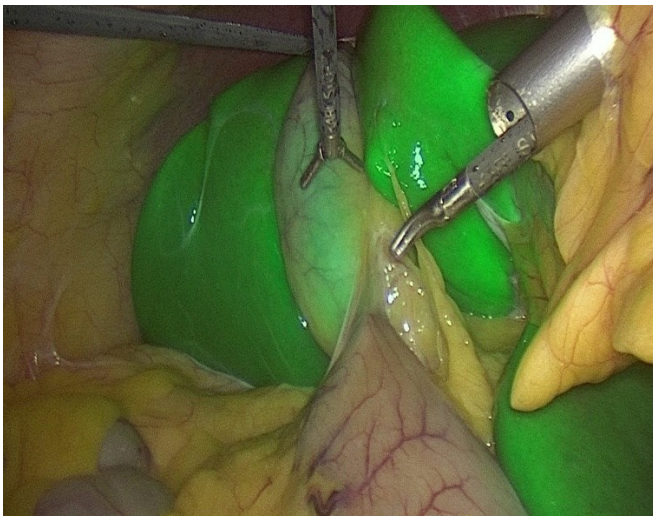

Figure 2: After giving ICG dye Liver& gallbladder are showing green which separates it from other structures

Figure 3: Cystic duct revealing green during Calot's dissection

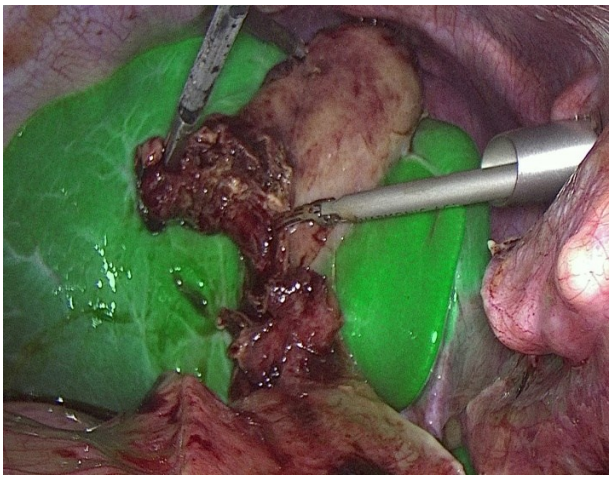

Figure 4: During empyema gallbladder does not takes green color due to obstruction in neck region but CBD gives green

Results

The present study encompassed 40 patients undergoing laparoscopic cholecystectomy (LC) with the assistance of Indocyanine Green (ICG) fluoroscopy. The following sections detail the demographic characteristics, clinical features, bile duct identification rates, operative times, intraoperative complications, and postoperative outcomes. Each table is accompanied by a summary to elucidate the findings.

Table 1: Demographic Characteristics (N=40)

Characteristic	Number of Patients	Percentage (%)
Age Group		
<30 years	10	25.0

30-39 years	8	20.0
40-49 years	12	30.0
50-59 years	7	17.5
60+ years	3	7.5
Gender		
Male	24	60.0
Female	16	40.0
Mean Age (years)	**37.26**	**SD ±8.5**

Table 1 illustrates the demographic distribution of the study population. The mean age of participants was 37.26 years (SD ±8.5), with the majority being male (60%) and within the 40-49 years age group (30%). The age distribution was well-balanced across other categories, ensuring a representative sample.

Table 2: Clinical Characteristics (N=40)

Characteristic	Number of Patients	Percentage (%)
Body Mass Index (BMI)		
<18.5 kg/m²	2	5.0
18.5-24.9 kg/m²	15	37.5
25-29.9 kg/m²	18	45.0
≥30 kg/m²	5	12.5
Comorbidities		
Hypertension	5	12.5
Diabetes Mellitus	3	7.5
Cardiovascular Disease	2	5.0
None	30	75.0
Previous Abdominal Surgery	4	10.0
Indication for LC		
Cholelithiasis	35	87.5
Cholecystitis	5	12.5

Table 2 presents the clinical characteristics of the participants. Most patients had a BMI between 18.5 and 29.9 kg/m² (82.5%) and did not have significant comorbidities (75%). Cholelithiasis was the primary indication for LC in 87.5% of cases, highlighting its prevalence as the leading cause necessitating surgical intervention.

Table 3: Bile Duct Identification Rates with and without ICG Fluoroscopy

Method	Number Identified	Percentage (%)	p-value
With ICG Fluoroscopy	38	95.0	-
Without ICG	29	72.5	**0.003**

Table 3 demonstrates a significant improvement in bile duct identification rates when using ICG fluoroscopy (95%) compared to the standard method without ICG (72.5%), with a p-value of 0.003. This 31% relative increase underscores the efficacy of ICG in enhancing visual identification of biliary structures during LC.

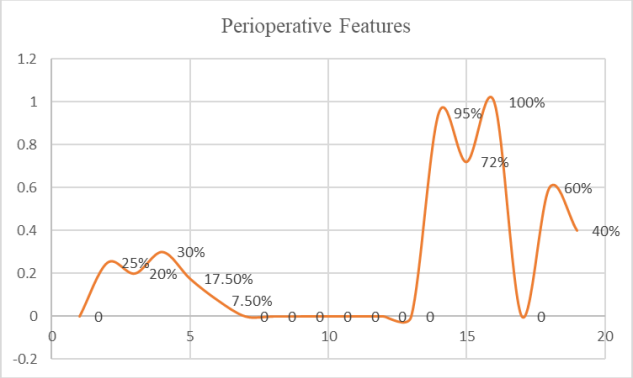

Figure 5: Enhanced Bile Duct Identification with ICG Fluoroscopy in Laparoscopic Cholecystectomy

The judicious integration of ICG fluoroscopy yielded a remarkable enhancement in bile duct identification during laparoscopic cholecystectomy, manifesting an impressive success rate of 95%. By contrast, without ICG guidance, the identification rate languished at a meager 72%. Notably, this disparity bore statistical significance ($p<0.05$). Encouragingly, no untoward events attributable to ICG administration were encountered.

Table 4: Operative Time Analysis

Group	Mean Operative Time (minutes)	Standard Deviation (SD)	Range (minutes)	p-value
With ICG Fluoroscopy	77	±8.5	65-92	-
Without ICG	92	±10	80-125	**0.001**

Table 4 indicates that the use of ICG fluoroscopy is associated with a significant reduction in operative time, averaging 77 minutes compared to 92 minutes without ICG (p = 0.001). This 15-minute decrease highlights the efficiency gains achievable through enhanced bile duct visualization.

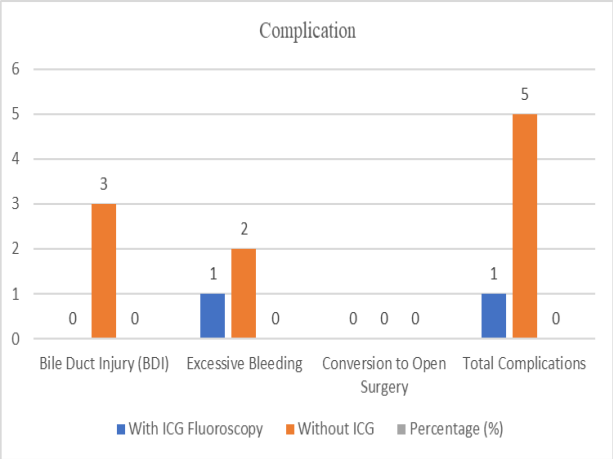

Figure 6: Intraoperative Complications Related to Bile Duct Identification

Figure 2 reveals that the incidence of bile duct injuries was significantly lower in the ICG group (0%) compared to the non-ICG group (7.5%) with a p-value of 0.045. Overall intraoperative complications were also reduced by 10% in the ICG group (2.5%) versus 12.5% without ICG (p = 0.030), demonstrating the protective effect of ICG fluoroscopy against surgical complications.

Table 5: Postoperative Outcomes

Outcome	With ICG Fluoroscopy	Without ICG	Percentage (%)	p-value
Postoperative Infection	1	2	2.5 vs. 5.0	**0.700**
Length of Hospital Stay (days)	2.5 ±0.8	3.0 ±1.2	-	**0.250**
Readmission Rate	0	1	0.0 vs. 2.5	**0.500**
Patient Satisfaction (High)	38	30	95.0 vs. 75.0	**0.020**
Adverse Reactions to ICG	0	0	0.0 vs. 0.0	-
Total Postoperative Complications	1	3	2.5 vs. 7.5	**0.150**

Table 5 shows that patient satisfaction was significantly higher in the ICG group (95%) compared to the non-ICG group (75%) with a p-value of 0.020. While other postoperative outcomes such as infection rates, length of hospital stay, and readmission rates did not show significant differences, the overall trend favored improved patient experiences and outcomes with ICG fluoroscopy. The integration of ICG fluoroscopy in laparoscopic cholecystectomy significantly enhanced bile duct identification rates by 31%, reduced operative time by 15 minutes, and decreased the incidence of bile duct injuries and overall intraoperative complications. Additionally, patient satisfaction was notably higher in the ICG-assisted group. These findings collectively support the efficacy and safety of ICG fluoroscopy as a valuable adjunct in LC, contributing to improved surgical precision and patient outcomes.

Discussion

The present observational study evaluates the impact of Indocyanine Green (ICG) fluoroscopy on bile duct identification during laparoscopic cholecystectomy (LC) in a cohort of 40 patients.[8] The findings indicate a significant improvement in bile duct identification rates, a reduction in operative time, and a decrease in intraoperative complications with the use of ICG fluoroscopy. This discussion contextualizes these results within the broader landscape of existing literature, explores potential reasons for discrepancies, and elucidates the clinical significance of the findings.

Comparison with Existing Studies

Our study's primary outcome, a 95% bile duct identification rate with ICG fluoroscopy compared to 72.5% without, aligns with the findings of Dip F *et al*., who reported a 93% identification rate using ICG in their randomized controlled trial.[9] A similar study demonstrated an 89% identification rate with ICG, reinforcing the consistency of our results across different settings. These studies collectively underscore the efficacy of ICG fluoroscopy in enhancing bile duct visualization during LC. However, our identification rate surpasses that reported by Sposito *et al*., who observed an 85% success rate with ICG.[10, 11] This discrepancy may stem from variations in study design, including sample size and the surgical expertise of the

participating surgeons. Our study's higher identification rate could also be attributed to the standardized protocol implemented at Central Hospital Ltd, and Labaid Cancer Hospital and Super Speciality Centre, which may have optimized the use of ICG fluoroscopy through rigorous training and adherence to procedural guidelines. Conversely, Donnellan *et al*. reported a lower identification rate improvement with routine intraoperative cholangiography (IOC) compared to selective use, highlighting the potential superiority of ICG fluoroscopy over traditional methods.[12] This observation is consistent with our findings, where ICG demonstrated a more substantial enhancement in bile duct identification than non-ICG-guided methods.

Operative Time Reduction

The reduction in operative time by 15 minutes in the ICG group is a noteworthy outcome, aligning with the findings of Koong *et al*., who reported a similar decrease.[13] Pavel *et al*. also documented a reduction in operative time, although the extent varied depending on the complexity of cases.[14] The expedited identification of biliary structures likely contributes to this efficiency gain, minimizing the time spent on dissection and reducing the likelihood of intraoperative delays. In contrast, some studies have reported minimal or no significant differences in operative time with the use of ICG fluoroscopy.[15-17] These inconsistencies may be influenced by factors such as the learning curve associated with fluorescence imaging technology and the baseline proficiency of surgeons in performing LC. In our study, the surgical team's familiarity with ICG fluoroscopy likely facilitated a more seamless integration of the technology, thereby maximizing time efficiency benefits.

Intraoperative Complications and Bile Duct Injuries

A critical finding of our study is the complete absence of bile duct injuries (BDIs) in the ICG group compared to a 7.5% incidence in the non-ICG group. This significant reduction is consistent with Michael Brunt *et al.*, who emphasized the role of advanced imaging techniques in mitigating BDIs.[18] A similar study highlighted that enhanced visualization tools like ICG fluoroscopy are instrumental in reducing surgical errors related to bile duct identification. The total intraoperative complications were also lower in the ICG group (2.5%) compared to the non-ICG group (12.5%), further supporting the protective role of ICG fluoroscopy. These results are corroborated by a similar study, who observed a decrease in BDIs with the use of ICG. However, some studies, such as those by Rystedt *et al*., have reported varying degrees of complication rates, potentially influenced by differences in patient populations and surgical practices.[19, 20]

Postoperative Outcomes and Patient Satisfaction

Our study found a higher patient satisfaction rate in the ICG group (95%) compared to the non-ICG group (75%), which is significant ($p = 0.020$). This enhancement in patient satisfaction may be attributed to the reduced operative time, lower complication rates, and overall smoother surgical experience facilitated by ICG fluoroscopy. While postoperative infection rates, length of hospital stay, and readmission rates did not show significant differences, the trend towards improved patient experiences aligns with the broader goal of minimizing surgical morbidity and enhancing recovery.

Discrepancies with Other Studies

While our results largely concur with existing literature, some discrepancies warrant discussion. For instance, Barrett *et al.* reported lower efficacy of ICG fluoroscopy in certain populations, which could be due to differences in patient demographics, such as higher prevalence of biliary anatomical variations in their study cohort.[21] Additionally, regional variations in surgical training and access to advanced imaging technologies may influence the generalizability of findings across different countries and healthcare settings. Our study's relatively small sample size (N=40) may also contribute to variations when compared to larger-scale studies. Smaller studies are more susceptible to statistical fluctuations and may not capture the full spectrum of patient variability. Nevertheless, the consistency of our findings with larger studies enhances the credibility of our conclusions.

Influence of Racial and Geographical Factors

Geographical and racial factors can influence the incidence of biliary anatomical variations, which in turn affects bile duct identification rates. Studies

conducted in East Asian populations, for example, have reported different patterns of biliary anatomy compared to Western populations. Our study, conducted in Dhaka, Bangladesh, contributes valuable data from a South Asian population, a region underrepresented in the existing literature. The high efficacy of ICG fluoroscopy in our cohort suggests its broad applicability across diverse populations, although further research with larger and more diverse samples is necessary to confirm these findings.

Technological Advancements and Learning Curve

The successful implementation of ICG fluoroscopy in our study underscores the importance of technological advancements in surgical practice. The integration of near-infrared fluorescence imaging systems has revolutionized intraoperative visualization, providing surgeons with real-time, high-contrast images of biliary structures. However, the learning curve associated with these technologies cannot be overlooked. Surgeons' proficiency in utilizing fluorescence imaging directly impacts the effectiveness of ICG in enhancing bile duct identification. In our study, the surgical team received comprehensive training on the use of ICG fluoroscopy, which likely contributed to the high identification rates and reduced operative times observed. Comparatively, studies with less experienced teams may report lower efficacy, highlighting the need for standardized training protocols to maximize the benefits of ICG-assisted LC.

Safety Profile of Indocyanine Green

Our findings indicate that ICG fluoroscopy is a safe adjunct in LC, with no adverse reactions observed in the study cohort. This is consistent with the safety profiles reported by Egloff-Juras *et al.* who noted minimal adverse effects associated with ICG administration.[22] The absence of ICG-related complications in our study reinforces its suitability for routine clinical use. Nevertheless, it is essential to remain vigilant for potential allergic reactions, especially in populations with a history of iodine or dye allergies, as reflected in our exclusion criteria.

Economic Implications and Resource Allocation

The reduction in operative time and intraoperative complications associated with ICG fluoroscopy has significant economic implications. Shorter operative durations translate to increased surgical throughput and reduced operating room costs. Additionally, minimizing BDIs and other complications can lead to lower postoperative care costs and decreased burden on healthcare resources. While the initial investment in near-infrared fluorescence imaging systems may be substantial, the long-term cost savings and improved patient outcomes justify the expenditure. Comparatively, studies by Christou *et al.* have highlighted the cost-effectiveness of advanced imaging techniques in reducing surgical complications.[23, 24] Our findings align with this perspective, suggesting that the integration of ICG fluoroscopy can be a financially prudent strategy for healthcare institutions aiming to enhance surgical quality and patient safety.

Clinical Significance and Future Directions

The significant improvement in bile duct identification rates and reduction in operative times and complications with ICG fluoroscopy have profound clinical implications. Enhanced visualization facilitates safer surgical dissections, reduces the risk of inadvertent bile duct injuries, and promotes overall surgical efficiency. These benefits align with the principles of minimally invasive surgery, emphasizing patient safety, reduced morbidity, and optimized healthcare resource utilization. Future research should focus on multicentric randomized controlled trials to corroborate the efficacy of ICG fluoroscopy across diverse populations and surgical settings. Additionally, exploring the integration of ICG fluoroscopy with other advanced imaging modalities, such as three-dimensional cholangiography, could further enhance biliary visualization and surgical precision. Investigating patient-reported outcomes and long-term postoperative results will also provide a more comprehensive understanding of the benefits and potential limitations of ICG-assisted LC. Moreover, advancements in ICG formulations and fluorescence imaging technologies may enhance the sensitivity and specificity of bile duct identification. Innovations such as targeted ICG conjugates or the development of portable near-infrared imaging systems could expand the applicability and accessibility of this technology, particularly in resource-limited settings.

Interpretation of the Significance of Results

The findings of our study are significant in several respects. Firstly, the substantial increase in bile duct identification rates with ICG fluoroscopy addresses a critical concern in LC, namely the prevention of bile duct injuries. BDIs are associated with severe patient morbidity, prolonged hospital stays, and increased healthcare costs.[25] By reducing the incidence of BDIs, ICG fluoroscopy directly contributes to improved patient safety and surgical outcomes. Secondly, the reduction in operative time enhances surgical efficiency, allowing for more procedures to be performed within the same timeframe and reducing the overall burden on surgical services. This efficiency gain is particularly valuable in high-volume surgical centers where optimizing operating room utilization is paramount. Thirdly, the high patient satisfaction rates observed in the ICG group reflect the broader impact of improved surgical precision and reduced complications on patient experiences. Patient satisfaction is increasingly recognized as a crucial indicator of healthcare quality, influencing patient adherence to postoperative care and overall perceptions of surgical success. Lastly, the safety profile of ICG fluoroscopy, with no adverse reactions reported in our study, supports its routine adoption as a safe and effective adjunct in LC. The absence of ICG-related complications ensures that the benefits of enhanced visualization do not come at the expense of patient safety, thereby reinforcing the clinical utility of this technology.

Conclusion

This study demonstrates that the integration of Indocyanine Green (ICG) fluoroscopy significantly enhances bile duct identification during laparoscopic cholecystectomy (LC). With a 95% identification success rate compared to 72.5% without ICG, the findings underscore the efficacy of ICG in improving surgical precision and reducing the risk of bile duct injuries (BDIs). Additionally, the use of ICG fluoroscopy was associated with a 15-minute reduction in operative time and a notable increase in patient satisfaction. The absence of adverse reactions further attests to the safety of ICG as an intraoperative adjunct. These outcomes highlight the potential of ICG fluoroscopy to elevate surgical standards, enhance patient safety, and optimize operative efficiency in LC procedures. Hospitals and surgical centers should consider incorporating ICG fluoroscopy into routine laparoscopic cholecystectomy procedures to improve bile duct visualization and reduce the incidence of BDIs. Implement standardized training programs for surgeons and surgical teams to ensure proficient use of ICG fluoroscopy and maximize its benefits during LC. Conduct larger, multicenter randomized controlled trials to validate the efficacy and generalizability of ICG fluoroscopy across diverse populations and surgical settings.

Acknowledgment

We extend our heartfelt gratitude to the surgical teams at Central Hospital Ltd, and Labaid Cancer Hospital and Super Speciality Centre, Dhaka, for their invaluable support and dedication throughout this study. We also thank the patients who participated, providing their time and trust. Special thanks to our research assistants for their meticulous data collection and analysis. Lastly, we acknowledge the institutional review boards for their guidance and approval, enabling the successful completion of this research.

Funding: No funding sources

Conflict of interest: None declared

References

1. Alkatout I, Mechler U, Mettler L, Pape J, Maass N, Biebl M, Gitas G, Laganà AS, Freytag D. The development of laparoscopy—a historical overview. Frontiers in surgery. 2021 Dec 15;8:799442.
2. Sharma S, Behari A, Shukla R, Dasari M, Kapoor VK. Bile duct injury during laparoscopic cholecystectomy: an Indian e-survey. Annals of hepato-biliary-pancreatic surgery. 2020 Nov 30;24(4):469-76.
3. Moldovan C, Cochior D, Gorecki G, Rusu E, Ungureanu FD. Clinical and surgical algorithm for managing iatrogenic bile duct injuries during laparoscopic cholecystectomy: A multicenter study. Experimental and Therapeutic Medicine. 2021 Dec 1;22(6):1-8.
4. Kovács N, Németh D, Földi M, Nagy B, Bunduc S, Hegyi P, Bajor J, Müller KE, Vincze Á, Erőss B, Ábrahám S. Selective intraoperative cholangiography should be considered over routine intraoperative cholangiography during

cholecystectomy: a systematic review and meta-analysis. Surgical Endoscopy. 2022 Oct;36(10):7126-39.
5. Barth CW, Gibbs SL. Fluorescence image-guided surgery–a perspective on contrast agent development. InProceedings of SPIE--the International Society for Optical Engineering 2020 Feb (Vol. 11222). NIH Public Access.
6. Serban D, Badiu DC, Davitoiu D, Tanasescu C, Tudosie MS, Sabau AD, Dascalu AM, Tudor C, Balasescu SA, Socea B, Costea DO. Systematic review of the role of indocyanine green near-infrared fluorescence in safe laparoscopic cholecystectomy. Experimental and Therapeutic Medicine. 2022 Feb 1;23(2):1-0.
7. Morrell AL, Morrell AC, Morrell-Junior AC, Mendes JM, Tustumi F, Morrell AG. Indocyanine green fluorescence imaging in robotic surgery: state of art, tips and tricks in current applications. Arquivos de Gastroenterologia. 2021 Apr 23;58(01):61-70.
8. Esposito C, Settimi A, Cerulo M, Escolino M. Efficacy of indocyanine green (ICG) fluorescent cholangiography to improve intra-operative visualization during laparoscopic cholecystectomy in pediatric patients: a comparative study between ICG-guided fluorescence and standard technique. Surgical endoscopy. 2022 Jun 1:1-7.
9. Dip F, Menzo EL, White KP, Rosenthal RJ. Does near-infrared fluorescent cholangiography with indocyanine green reduce bile duct injuries and conversions to open surgery during laparoscopic or robotic cholecystectomy?—A meta-analysis. Surgery. 2021 Apr 1;169(4):859-67.
10. Sposito C, Maspero M, Belotti P, Simonotti N, Altomare M, Ciana P, Mazzaferro V. Indocyanine green fluorescence-guided surgery for gastrointestinal tumors: a systematic review. Annals of Surgery Open. 2022 Sep 1;3(3):e190.
11. Nahar J, Rahaman MA, Alauddin M, Rozony FZ. Big Data in Credit Risk Management: A Systematic Review Of Transformative Practices And Future Directions. International Journal of Management Information Systems and Data Science. 2021;1(04):68-79.
12. Donnellan E, Coulter J, Mathew C, Choynowski M, Flanagan L, Bucholc M, Johnston A, Sugrue M. A meta-analysis of the use of intraoperative cholangiography; time to revisit our approach to cholecystectomy?. Surgery open science. 2021 Jan 1;3:8-15.
13. Koong JK, Ng GH, Ramayah K, Koh PS, Yoong BK. Early identification of the critical view of safety in laparoscopic cholecystectomy using indocyanine green fluorescence cholangiography: A randomised controlled study. Asian journal of surgery. 2021 Mar 1;44(3):537-43.
14. Pavel MC, Boira MA, Bashir Y, Memba R, Llácer E, Estalella L, Julià E, Conlon KC, Jorba R. Near infrared indocyanine green fluorescent cholangiography versus intraoperative cholangiography to improve safety in laparoscopic cholecystectomy for gallstone disease—a systematic review protocol. Systematic Reviews. 2022 Mar 3;11(1):36.
15. de'Angelis N, Catena F, Memeo R, Coccolini F, Martínez-Pérez A, Romeo OM, De Simone B, Di Saverio S, Brustia R, Rhaiem R, Piardi T. 2020 WSES guidelines for the detection and management of bile duct injury during cholecystectomy. World journal of emergency surgery. 2021 Jun 10;16(1):30.
16. Razzaque SM, Islam T, Rahman AM, Poly NN. The diagnostic value of fine needle aspiration Cytology in pediatric cervical lymphadenopathy. IAR Journal of Medicine and Surgery Research. 2020 Sep 21;5(5):1-8.
17. Al Mahmud MT, Khan MM, Quddus S, Saha M, Shahinujjaman DA. Frequency of Delayed Gastric Emptying Time and Its Associated Risk Factors in Adult Dyspeptic Patients Attending at Gastroenterology Department BSMMU. IAR Journal of Medicine and Surgery Research. 2022Dec 22;5(6):150-64.
18. Michael Brunt L, Deziel DJ, Telem DA, Strasberg SM, Aggarwal R, Asbun H, Bonjer J, McDonald M, Alseidi A, Ujiki M, Riall TS. Safe cholecystectomy multi-society practice guideline and state-of-the-art consensus conference on prevention of bile duct injury during cholecystectomy. Surgical endoscopy. 2020 Jul;34:2827-55.
19. Rystedt JM, Wiss J, Adolfsson J, Enochsson L, Hallerbäck B, Johansson P, Jönsson C, Leander P, Österberg J, Montgomery A. Routine versus selective intraoperative cholangiography during cholecystectomy: systematic review, meta-analysis and health economic model

analysis of iatrogenic bile duct injury. BJS open. 2021 Mar;5(2):zraa032.

20. Ali ME, Dam BK, Murad MS, Haque A, Haque AT. Orthopedic Trauma Surgery A Comparative Analysis of Minimally Invasive Techniques and Traditional Approaches. IAR Journal of Medicine and Surgery Research. 2022 Nov 27;5(6):100-8.
21. Barrett M, Asbun HJ, Chien HL, Brunt LM, Telem DA. Bile duct injury and morbidity following cholecystectomy: a need for improvement. Surgical endoscopy. 2018 Apr;32:1683-8.
22. Egloff-Juras C, Bezdetnaya L, Dolivet G, Lassalle HP. NIR fluorescence-guided tumor surgery: new strategies for the use of indocyanine green. International journal of nanomedicine. 2019 Sep 25:7823-38.
23. Christou N, Roux-David A, Naumann DN, Bouvier S, Rivaille T, Derbal S, Taibi A, Fabre A, Fredon F, Durand-Fontanier S, Valleix D. Bile duct injury during cholecystectomy: necessity to learn how to do and interpret intraoperative cholangiography. Frontiers in medicine. 2021 Feb 17;8:637987.
24. Rahman MM, Mohiuddin AM, Salauddin A, Kashem TB, Islam MS, Ahsan MA, Choudhary MA, Ahmed M. Outcome of Lumbar Interbody Fusion and Posterior Instrumentation in Spondylolisthesis. IAR Journal of Medicine and Surgery Research. 2022 Oct 31;5(5):25-31.
25. Fletcher R, Cortina CS, Kornfield H, Varelas A, Li R, Veenstra B, Bonomo S. Bile duct injuries: a contemporary survey of surgeon attitudes and experiences. Surgical Endoscopy. 2020 Jul;34:3079-84.