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EMPRESA DE INVESTIGACIÓN SABERES Y CONOCIMIENTOS TECHGACETI CIA. LTDA.

Use of indocyanine green (ICG) fluorescence in laparoscopic surgery: benefits in anatomical identification and prevention of biliary injuries. A systematic review

Uso de la fluorescencia con verde de indocianina (ICG) en cirugía laparoscópica: beneficios en la identificación anatómica y la prevención de lesiones biliares. Una revisión sistemática

Utilização da fluorescência do verde de indocianina (ICG) na cirurgia laparoscópica: benefícios na identificação anatómica e prevenção de lesões biliares. Uma revisão sistemática

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ABSTRACT

The objective of this study is to discuss the use of indocyanine green (ICG) fluorescence in laparoscopic surgery, as well as its benefits in anatomical identification and the prevention of biliary injuries. We delve deeply into topics related to laparoscopy and the risk of biliary injuries, factors predisposing to the development of biliary lithiasis, the Amsterdam classification describing bile leaks and strictures, the use of ICG fluorescence in laparoscopic surgery, and an introduction to ICG technology. Regarding the methodological guidelines, this study was characterized as a PRISMA-type systematic review. Inclusion and exclusion criteria were applied, along with keywords in both English and Spanish, to construct search strings for databases such as Google Scholar, SciELO, and Elsevier. Finally, it was concluded that the administration of indocyanine green (ICG) fluorescence in laparoscopic surgery is highly useful. It is an efficient method that aids in the precise, real-time visualization of anatomical structures of the biliary ducts, the cystic duct, and blood vessels, thereby reducing the probability of accidental injuries to the biliary tree and other surrounding tissues. Within the surgical process, it allows the surgeon to perform dissection precisely, avoiding iatrogenic injuries due to the clear identification of anatomical structures, which prevents complications during surgery.

Keywords: Laparoscopic surgery, Laparoscopy, Indocyanine green, ICG, Fluorescence, Fluorescent imaging.

RESUMEN

El objetivo de este estudio es analizar el uso de la fluorescencia con verde de indocianina (ICG) en la cirugía laparoscópica, así como sus beneficios en la identificación anatómica y la prevención de lesiones biliares. Profundizamos en temas relacionados con la laparoscopia y el riesgo de lesiones biliares, los factores que predisponen al desarrollo de litiasis biliar, la clasificación de Ámsterdam que describe las fugas y estenosis biliares, el uso de la fluorescencia ICG en la cirugía laparoscópica y una introducción a la tecnología ICG. En cuanto a las pautas metodológicas, este estudio se caracterizó como una revisión sistemática de tipo PRISMA. Se aplicaron criterios de inclusión y exclusión, junto con palabras clave en inglés y español, para construir cadenas de búsqueda para bases de datos como Google Scholar, SciELO y Elsevier. Finalmente, se concluyó que la administración de fluorescencia con verde de indocianina (ICG) en la cirugía laparoscópica es muy útil. Se trata de un método eficaz que ayuda a visualizar con precisión y en tiempo real las estructuras anatómicas de los conductos biliares, el conducto cístico y los vasos sanguíneos, lo que reduce la probabilidad de lesiones accidentales en el árbol biliar y otros tejidos circundantes. Dentro del proceso quirúrgico, permite al cirujano realizar la disección con precisión, evitando lesiones iatrogénicas gracias a la clara identificación de las estructuras anatómicas, lo que previene complicaciones durante la cirugía.

Palabras clave: Cirugía laparoscópica, Laparoscopia, Verde de indocianina, ICG, Fluorescencia, Imágenes fluorescentes.

RESUMO

O objetivo deste estudo é discutir o uso da fluorescência do verde de indocianina (ICG) na cirurgia laparoscópica, bem como os seus benefícios na identificação anatómica e na prevenção de lesões biliares. Aprofundamos temas relacionados à laparoscopia e ao risco de lesões biliares, fatores predisponentes ao desenvolvimento de litíase biliar, a classificação de Amsterdã que descreve vazamentos e estenoses biliares, o uso da fluorescência ICG na cirurgia laparoscópica e uma introdução à tecnologia ICG. No que diz respeito às diretrizes metodológicas, este estudo foi caracterizado como uma revisão sistemática do tipo PRISMA. Foram aplicados critérios de inclusão e exclusão, juntamente com palavras-chave em inglês e espanhol, para construir cadeias de pesquisa para bases de dados como Google Scholar, SciELO e Elsevier. Finalmente, concluiu-se que a administração da fluorescência do verde de indocianina (ICG) na cirurgia laparoscópica é altamente útil. É um método eficiente que auxilia na visualização precisa e em tempo real das estruturas anatómicas dos ductos biliares, do ducto cístico e dos vasos sanguíneos, reduzindo assim a probabilidade de lesões acidentais na árvore biliar e outros tecidos circundantes. Dentro do processo cirúrgico, permite ao cirurgião realizar a dissecção com precisão, evitando lesões iatrogénicas devido à identificação clara das estruturas anatómicas, o que previne complicações durante a cirurgia.

Palavras-chave: Cirurgia laparoscópica, Laparoscopia, Verde de indocianina, ICG, Fluorescência, Imagem fluorescente.

Introduction

Indocyanine green (ICG) fluorescence for laparoscopic surgery, is a tool helps to improve the visualization, safety of this type of surgical procedures, because it can be seen with greater precision all anatomical structures of the biliary tree, facilitates the distinction of bile ducts, blood vessels, cystic duct avoiding the probability of iatrogenic injuries. Even ICG, allows detection of sentinel lymph nodes in oncological surgery, the identification of tumors and the evaluation of tissue viability (1).

It is opportune to point out that indocyanine green (ICG) according to what was described by Pérez et al (2) is a drug that is used in medicine to evaluate tissue perfusion during surgical procedures. Its fluorescent properties allow it to be visualized with infrared probes, which makes it useful to visualize vascular structures and evaluate blood circulation in different tissues. It is administered intravenously and is distributed rapidly through highly vascularized sites due to its affinity for plasma proteins. Indocyanine green can have adverse reactions, but in general the possibility of serious or lethal events is low, which makes it a safe option for intraoperative use. Its process of hepatic metabolization and biliary excretion makes it especially useful in hepatobiliary-pancreatic surgeries where clarity about the structures of the biliary tree is required, iatrogenic injuries of the biliary tract are a considerable challenge, with an incidence of 0.4-0.6% in laparoscopic cholecystectomy.

Likewise, Pérez et al (2) indicate that the chemical formula of indocyanine green is: $C_{43}H_{47}N_2NaO_6S_2$ is a complex organic compound that belongs to the cyanine family. Its molecular structure includes two indolenine rings joined by a conjugated carbon chain, which gives it its fluorescence properties. Molecular weight: 774.97 g/mol. Color: Intense green. Fluorescent properties: Emits near-infrared light when excited with visible light. Solubility: Soluble in water and in some polar organic solvents. Indocyanine green is a fluorescent tricarbocyanide stain visible with near-infrared light or by laser systems, with absorption and emission peaks of 805-835nm, respectively. Fluorescence is detected through the use of specific cameras that transmit this signal to a monitor, through which the structures in which the stain is found can be identified, which was approved by the Food and Drug Administration in 1956.

The present document makes mention of the use of fluorescence with indocyanine green (ICG) in laparoscopic surgery and the benefits in anatomical identification and prevention of biliary injuries. Similarly, aspects related to laparoscopy and the risk of biliary injuries, factors that predispose to the development of biliary lithiasis, the Amsterdam classification, which describe biliary leaks and strictures, use of fluorescence with indocyanine green (ICG) in laparoscopic surgery and Introduction to ICG technology: how it works, physiological basis.

Methodology

The methodology of the present investigation is a PRISMA systematic review, on "Use of indocyanine green (ICG) fluorescence in laparoscopic surgery: benefits in anatomical identification and prevention of biliary injuries." For which an exhaustive search was carried out in databases such as Google Scholar, Scielo, and Elsevier, applying keywords both in English (Laparoscopic surgery OR Laparoscopy) AND (Indocyanine green OR ICG) AND (Fluorescence OR Fluorescent imaging) AND (Anatomical identification OR Anatomical landmarks) AND (Biliary injury OR Bile duct injury OR Biliary complications) as well as in Spanish (Cirugía laparoscópica OR Laparoscopia) AND (Verde de indocianina OR ICG) AND (Fluorescencia OR Imagen de fluorescencia) AND (Identificación anatómica OR Referencias anatómicas) AND (Lesión biliar OR Lesión de vía biliar OR Complicaciones biliares). **Inclusion and Exclusion Criteria**. Among the inclusion criteria selected were: bibliographic references from the last 5 years (2020-2025), research papers both in English and Spanish, that address the subject matter of the investigation. For which the title of the work was read in the first instance, then the abstract was read in a second moment, and finally, as a definitive discarding or inclusion process, the conclusion. **As exclusion criteria were discarded:** bibliography not within the established range (with the exception of some research article whose information is very relevant for the present work), bibliography that addresses a different subject matter from the central objective of the present investigation, bibliography in languages other than English or Spanish, repeated bibliographies, bibliographies without open access. The summary of the articles found in the database is summarized in Table 1. As well as in Table 2, the selected articles are presented after applying the inclusion and exclusion criteria.

Table 1. Summary of articles found in database

Database	Articles found
Google Scholar	86
Scielo	15
Elsevier	14
Total	**115**

Table 2. Selection of primary articles after applying the inclusion and exclusion criteria

Database	Selected articles
Google Scholar	12
Scielo	3
Elsevier	1
Total	**16**

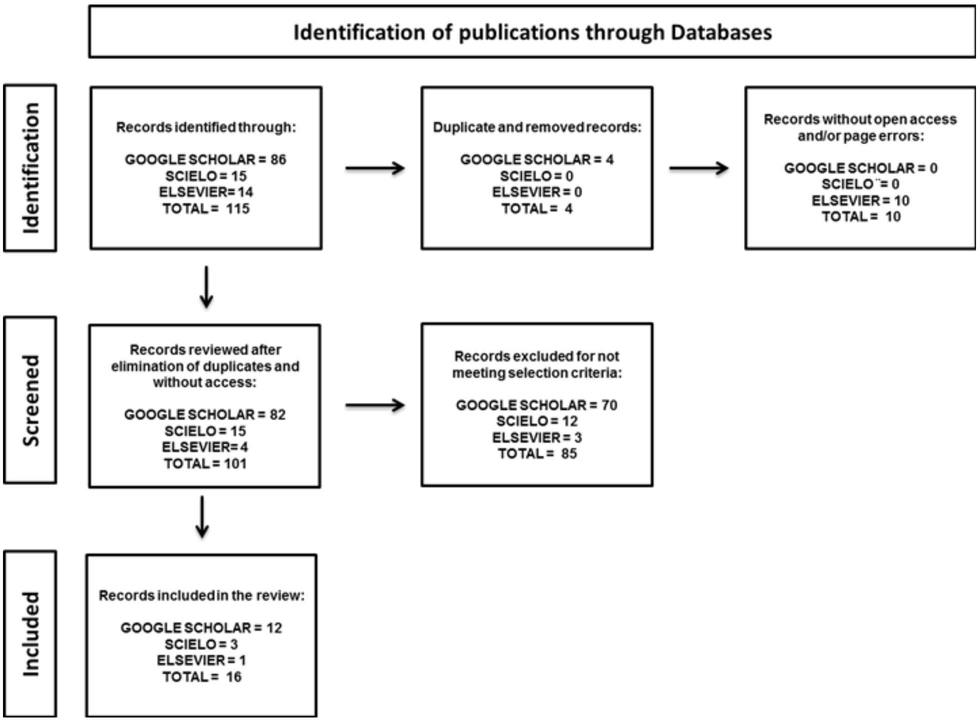

Figure 1. Flow Diagram of Selected Studies

Results

It is worth noting that during laparoscopic cholecystectomy procedures, injuries to the bile ducts can occur, and these can vary in their level of severity according to Davila et al (10). These injuries are produced during any surgical procedure and can occur in any part of the biliary tract and comprise 95% of benign strictures of the biliary tract. The Bismuth and Strasberg classifications are important tools to evaluate and classify bile duct injuries in laparoscopic cholecystectomy and provide crucial information about the location, extent, and severity of the injuries, which guides surgical planning and helps in the prognosis and treatment of affected patients.

In relation to the confluence of the hepatic ducts, Davila et al (10) express that it is very frequent in this surgical intervention, having several classifications, the most common being type III and type I of the Bismuth classification. These compromise the vessels and pedicle, with their treatment being bilioenteric anastomosis with Roux-en-Y with a mortality rate of 5%.

It is opportune to indicate that laparoscopic cholecystectomy is a procedure that seeks to minimize incisions to reduce the risk of BDI (Biliary Duct Injury), but its application requires caution on the part of medical personnel. Likewise, Rojas & Vera (7) indicate that factors such as obesity and aging increase the risk, and key strategies such as surgical meticulousness, adequate interpretation of anatomical variants, and conversion to open procedures are essential to prevent these injuries. Common errors involve a misinterpretation of anatomy, especially the confusion of the hepatic duct with the cystic or other factors such as inflammation in Calot's triangle, short cystic duct, excessive cephalic retraction, lateral retraction, and excessive tension at the choledocho-cystic junction contribute to BDI.

For Rojas & Vera (7), it is considered that prompt identification and treatment of these injuries are crucial to mitigate possible complications, such as biliary fistulas, intra-abdominal abscesses, strictures, recurrent cholangitis, and secondary biliary cirrhosis or stricture up to portal hypertension and cirrhosis; they encompass multiple classifications grouping these injuries according to their location and extent. In this context, the aim is to review and update the risk factors, types of biliary tract injuries, and treatment approaches related to these complications.

Similarly, Rojas & Vera (7) mention two classification systems used in the medical field to categorize different types of complications related to the biliary tract during surgical procedures. In the Amsterdam classification, four types (A, B, C, and D) are identified that describe bile leaks and strictures, specifying the location and severity of the ductal involvement. On the other hand, the Strasberg classification also addresses situations in which an inadvertent cut of the cystic, hepatic, and common bile ducts occurs, categorizing them as types A, B, C, D, and E, the latter referring to biliary tract laceration.

Table 3. Amsterdam Classification

Amsterdam Classification	Description	Strasberg Classification	Description
Type A	Minor bile leak affecting peripheral ducts (cystic, terminal ducts, or Luschka)	Type A	Inadvertent cut of the cystic duct
Type B	Major bile leak affecting main ducts (common bile duct, common hepatic, right or left hepatic), with or without stricture	Type B	Inadvertent cut of the cystic duct with injury to the common hepatic duct or common bile duct
Type C	Bile duct stricture without leak	Type C	Inadvertent cut of the common hepatic duct or common bile duct
Type D	Duct section or resection, with or without surgical ligation or stapling.	Type D	Inadvertent cut of the right or left bile duct
Classification of Biliary Leaks		Type E	Laceration of the biliary tract.
Low-Grade Biliary Leaks	Become evident after opacifying the intrahepatic biliary tree		
High-Grade Biliary Leaks	Are evident before opacifying the intrahepatic biliary tract.		

Source: Rojas & Vera (7).

Additionally, Rojas & Vera (7) highlight the distinction between low-grade biliary leaks, which become evident after opacifying the intrahepatic biliary tree, and high-grade biliary leaks, which are detected before performing said opacification. Both systems provide detailed guidance for the classification and understanding of biliary complications, being valuable tools in the surgical and medical field.

It is important to explain that the pathologies of the biliary tract described by Rojas & Vera (7), citing Gonzales and Vergara, are one of the most frequent diseases in the digestive system and have been declared one of the diseases that has affected a large population worldwide. However, factors such as age or obesity are important. Nevertheless, among the complications associated with biliary tract injuries, the Faculty of Medical

Sciences in Asunción in December 2021 describes bile leakage, jaundice caused by obstruction, and hepatic ischemia after a vascular injury.

Table 4. Dosage and administration time of ICG used in CL

Authors	Type of Study	Dose	Administration Time Prior to CL
Dip F, Sarotto L, Stassen L et al	Literature Review	0.05 mg/kg - 2.5 mg	45 to 60 minutes
Vlek S, van Dam D, Rubinstein S et al	Systematic Literature Review	0.05 mg/kg - 2.5 mg	45 to 60 minutes
Guillen G, LópezFernández J, Molino	Pilot Series	2.5 mg/kg	45 minutes
Palafox S	Thesis	2.5 to 10 mg	30 minutes to 2 hours
Ankersmit M, van Dam D, van Rijswijk A-S	Case Study	0.2 mg/kg to 0.5 mg/kg	30 to 60 minutes
Zarrinpar A, Dutson E, Mobley C	Prospective Study	0.02 to 0.25 mg/kg	5 to 15 minutes, 45 minutes, 1 hour
Boogerd L, Handgraaf H, Huurman V, Lam H-D	Systematic Literature Review	2.5 mg, 5 mg, 10 mg	During the hour prior to CL, 30 to 60 min, 24 hours
Boogerd L, Handgraaf H, Huurman V, Lam H-D	Clinical Trial	5 mg, 10 mg	3 to 6 hours, 5 to 23 hours
Agnus V, Pesce A, Boni	Online Secured Database (EURO-FIGSb)	0.3 mg/kg	6 hours

Source: López & Velásquez (1).

Fluorescent Image-Guided Surgery

For fluorescent image-guided surgery, López & Velásquez (1) indicate that a solution is prepared with a 25 mg vial of ICG powder and dissolved in 10 ml of sterile water, resulting in a 2.5 mg/ml dye solution. Subsequently, 1 ml of the previously prepared solution is dissolved in 9 ml of sterile water to obtain a 0.25 mg/ml solution. Intraoperatively, after preparation, a Kumar cholangiography catheter is used, introduced through the umbilical port once the fundus of the gallbladder is held and retracted. Guided by a dissection instrument, the infundibulum of the gallbladder is punctured with the Kumar catheter, where 9 ml of bile are aspirated through the needle that said catheter possesses, which are then mixed in a syringe with 1 ml of the ICG solution, creating a 0.025 mg/ml ICG/bile solution. This mixture, when reinjected into the gallbladder, immediately stains the structures, spreading to the cystic duct and the rest of the extrahepatic bile ducts. When the Kumar catheter is removed, the puncture site is obliterated with a Maryland clamp.

Table 5. Results of the use of the intravesicular ICG injection technique

Authors	Solution Concentration	Number of Patients Where Technique Was Used	Results of Biliary Anatomy Visualization in LC
Graves C, Sora E, Idowu O	0.025 mg/ml	11	90.9% visualization rate of the total length of the CBD
Nitta T, Kataoka J, Ohta M	0.025 mg/mL	1	Successful and rapid detection of the CC and CBD
Skrabec C, Pardo F, Espin F	0.25 mg/mL	20	80% visualization rate of Hartmann's pouch
Liu Y-Y, Liao C-H, Diana M	0.125 mg/mL	46	77.8%* and 100% visualization rates of the CC
Shibata H, Aoki T, Koizumi T	0.025 mg/ml	12	100% visualization rates of CC, CBD, and CHD in all 3 structures

Source: López & Velásquez (1).

Applications in Laparoscopic Surgery

Regarding the application of laparoscopic surgery, Farfán Feijoo et al (3) state that the Mexican Social Security Institute distinguishes three types, which are explained below: Exploratory laparoscopy and diagnostic or therapeutic laparoscopy, and indicate:

1. **Exploratory Laparoscopy:** Surgical opening of the abdomen, and review of the abdominal and pelvic organs. It is the exploration of the abdominal cavity through optics introduced through orifices in the abdomen and whose purpose is the observation of the abdominal organs, which is carried out through small incisions through a needle that inflates gas (CO_2) and trocars; it can be Diagnostic or Therapeutic.

2. **Diagnostic or Therapeutic Laparoscopy:** Laparoscopic technique or intervention for the purpose of exploring and studying organs and systems. In this same vein, Morales Alfaro, Américo, Quispe Rojas Wanda Thongshi, Velasquez Delgado Fredy and Fernandez Yupanqui Lenin (5), point out in their study carried out circumscribed to "frequent surgical pathology was gynecological, biliary and appendicular."

3. **Diagnostic Laparoscopy (LDx):** It is a modality of laparoscopy whose fundamental objective is to determine the pathology causing a specific clinical picture, in which a precise diagnosis could not be reached. This can be therapeutic in many cases, those in which it is feasible by laparoscopic surgery and in which the surgeon is trained to perform it. The techniques followed are the same as standard abdominal or thoracic laparoscopy. Exploratory Laparotomy (EL): Any laparotomy used with the purpose of reaching a diagnosis that could not be determined through the clinical picture and complementary examinations.

According to Farfán Feijoo et al (3), it can have utilities for exploratory laparotomy and diagnostic laparoscopy because it examines organs and structures, so its benefits are stated, indicating the following:

1. Acute abdominal pain.
2. Staging of oncological pathology.
3. Release of adhesions.
4. Ablation of endometriosis.
5. Aspiration of ovarian cysts.
6. Chronic pelvic pain.
7. Dysmenorrhea in adolescents.

8. Diagnosis and follow-up of endometriosis.
9. Second Look: Reintervention for cancer for prognosis and treatment.
10. The authors mentioned above in the investigative work called.

According to Farfán Feijoo et al (3) indicates that the main reason for choosing the exploratory laparotomy (EL) technique is acute abdomen, unlike diagnostic laparoscopy (DL) whose main reason for choice is to determine the cause of infertility; this may be an indication of the limited knowledge of the wide utility offered by DL, as well as a consequence of it still being a developing technique.

1. The diagnostic results with both techniques do not have significant variation, so they can be alternatively replaced.
2. The minimum percentage of postoperative complications occurs in DL.
3. The maximum average length of hospital stay occurs in EL.
4. The analysis of the operation performed in relation to the diagnosis demonstrates a similar utility of DL and EL for making diagnoses, although the therapeutic utility for definitive cure is surpassed in EL.
5. The operative time of LDx is less than that established in EL, which decreases exposure to damage from surgical trauma.
6. In accordance with previous studies, the advantages of smaller incision size are confirmed in the lesser need for use in number, time, and intensity of analgesic drugs.
7. DL is a simple, safe, and inexpensive procedure; the morbidity and mortality of the procedure are low when performed with appropriate indications and by trained personnel.
8. DL has increased significantly in both emergency and hospitalization surgical services, due to the definitive advantages that this method has and that translates into a decrease in the cost-benefit ratio for both the patient and our institutions.

It is important to highlight that laparoscopy for Farfán Feijoo et al (3) has diverse uses explaining the following: In general, its common use is to detect a medical problem such as chronic pelvic pain (pain lasting more than six months), and also, to carry out a series of minor and complex operations or surgeries carried out with the help of a camera with a few small incisions mainly in the abdomen or pelvis. With laparoscopy, a condition can also be diagnosed. In this case, the procedure is called diagnostic laparoscopy. Tissue samples can also be obtained for medical examinations and tests. Through this technique, practically any abdominal and pelvic surgery can be performed, among some of them are appendectomies, cholecystectomies, cystectomies, pancreatectomies, intestinal resections, and surgical sterilizations, and all of these can be done using the umbilicus as an entry point for the trocar. In gynecological matters, for example: cystectomies, hysterectomies, endometriosis cauterization, myomectomies, release of adhesions, infertility, tubal ligations, etc.

Benefits of Laparoscopic Surgery

Minimally Invasive Surgery (MIS) techniques or procedures, according to Farfán Feijoo et al (3), present several advantages, especially for the patient and healthcare entities, which has led to a wide interest in recent years in the utilization and advancement of such techniques in different fields of surgery, such as: abdominal surgery, cardiac surgery, traumatology, neurosurgery, and orthopedics, etc. Among the advantages presented by the literature regarding open surgery, the minimally invasive laparoscopic surgical technique presents several advantages, among them:

1. Faster recovery improving early mobilization, general and emotional state of the patient.

2. Hospital stay decreases due to faster recovery.
3. Postoperative pain is much less and, consequently, the intake of analgesics is reduced as the patient feels well.
4. Smaller wounds.
5. Less bleeding.
6. More precise sutures.
7. Less tissue separation to access the area to be treated.
8. Faster return to normal activity.
9. The patient's work leave time is shorter.
10. Results similar or superior to open surgery.
11. Reduction of intervention costs.
12. Hardly leaves a scar. The three or four incisions become almost invisible over time.
13. The possibility of wound complications such as: infection or eventrations, hernias in the operative wound, are reduced to very low percentages.

The lesser manipulation of tissues and intestine when performed with finer forceps, means that the risk of adhesions between tissues decreases and that the intestine recovers its mobility sooner, so food intake begins earlier.

However, laparoscopic surgery presents a series of disadvantages for the surgeon. This is explained by Farfán Feijoo et al (3), where each of them is indicated and it is considered that they should be taken into account in order to avoid situations that affect the health of patients:

Restricted vision of the operative field as it is performed through a mini-camera that sends the signal to a monitor.

- Restricted mobility of surgical instruments.
- Difficulty in handling instruments.
- Magnification of the surgeon's movements, such as tremors, etc.
- Among the physiological and pathological ones are:
- An exaggerated pneumoperitoneum can compress the diaphragm and the base of the lungs, leading to postoperative hypoxemia.
- Previous adhesions can prevent obtaining a pneumoperitoneum.
- There is a risk of gas embolism, although it is very rare.
- Tactile information is lost, which is important in the evaluation of some localized disorders. That is, null tactile perception for the surgeon with the exception of force feedback.
- Precise control of bleeding is more difficult.

Applications in Laparoscopic Surgery: Biliary Mapping

Laparoscopic biliary mapping surgery, according to Garnica (13), states that Dr. Nguyen coined the term "strategic laparoscopic surgery," defining it as laparoscopic surgery where aesthetic results are improved compared to the conventional technique, but maintaining the same level of safety and feasibility of the latter. Kuroki was one of the pioneers in describing the reduced-port laparoscopic cholecystectomy technique in 2011, and since then, multiple modifications have been made to it, each with different advantages and disadvantages.

Regarding the TILC technique, Garnica (13), citing Abaid, Cecconello, and Zilberstein, states that it is a procedure which can be performed with the same instrumentation and experience of a surgical team trained in CLC, making the pertinent changes mentioned above. Although two ports are placed in a single incision, the most important foundation of laparoscopic surgery, which is the principle of triangulation, is not infringed. Once the steps of the technique are followed, the rest of the procedure is indifferent to the conventional one, even allowing in most cases for a good critical safety view. However, the most important technical disadvantage is perhaps the collision of the forceps in the umbilical trocars. In experience, this can be avoided by positioning the optic on as vertical an axis as possible (taking advantage of being 30°) and not getting too close to the operative field when the main surgeon is using the third trocar's forceps; once the forceps have been secured at a point where they do not need to be mobilized, the cameraman can approach without problems. Another way to avoid this problem is the correct placement of the trocars at the beginning of the surgery: within the same umbilical incision, the further apart the introduction orifices of both trocars are and the more they are placed on a different rotational axis (creating a kind of "X" between them), the lower the probability of inter-instrument collision.

For Garnica (13), the greatest advantage provided by the TILC technique is regarding the cosmetic result and postoperative pain. The data from the present study reveal that pain is significantly less when quantified at 24 hours' post-surgery following the already mentioned instrument. This may be related to the reduction in the number of skin incisions made in this procedure, unlike the conventional method. Regarding the aesthetic outcome, it is directly related to the reduction in the number of scars on the abdominal wall, since the TILC technique uses 2 trocars in a single incision that corresponds to the umbilical scar, almost imperceptible. The other important point to highlight is that this surgical procedure is performed in a similar operative time and with a similar complication rate to the conventional technique, being statistically non-significant, so it is considered safe and effective, without emphasizing that there is no need to use different instruments or have a specific learning curve, so the costs of the surgery are practically identical.

Likewise, Garnica (13) mentions cases where the surgery had to be converted; in the TILC group, there was a need to place an extra trocar in a patient with a history of cholangitis and endoscopic instrumentation of the biliary tract, since among the intraoperative findings, a partially intrahepatic thick-walled gallbladder stood out, whose mobilization was not feasible using only the method of fundal retraction with the trans-parietal needle. In the consulted literature, it is evident that the conversion rates for this procedure are 3-5% in difficult cases, making the clarification that the term "conversion" in this context is not synonymous with open surgery, but rather refers to the act of placing one or two extra trocars to facilitate the surgical procedure.

Laparoscopic cholecystectomy, according to Garnica (13), has revolutionized gallbladder surgery since its introduction in 1985, becoming the gold standard for the treatment of symptomatic gallstone disease. This procedure has proven to be superior to traditional open surgery in terms of aesthetic results, less postoperative pain, and faster recovery, allowing patients to return to their daily activities in less time. Over the years, the laparoscopic technique has been refined and expanded to include a variety of indications, from cholelithiasis to acute cholecystitis and gallstone pancreatitis. However, it is crucial to consider contraindications and carefully evaluate patients with significant comorbidities, as general anesthesia and pneumoperitoneum can increase risks in certain groups.

For Garnica (13), the success of laparoscopic cholecystectomy also depends on the surgeon's skill and experience, especially in complicated cases such as acute cholecystitis or the presence of adhesions. Precise identification of anatomy and the application of safe techniques, such as critical view of safety, are fundamental to minimize intraoperative and postoperative complications. In summary, laparoscopic cholecystectomy has not only improved surgical outcomes and patient quality of life but has also established a new paradigm in minimally access surgery. As technology and techniques continue to advance, this procedure is likely to remain a cornerstone in abdominal surgery, benefiting an increasing number of patients worldwide.

Evaluation of the Biliary Tree

The evaluation of the biliary tree, according to Haggerty et al (14), can be performed using intraoperative cholangiography or laparoscopic ultrasound to assess the biliary tree. This allows for evaluating biliary anatomy (duct size, integrity, anatomical variations, presence of stones) and characterizing stones (location, size, number). Ultimately, it helps the surgeon decide the optimal approach for common bile duct exploration (transcystic or transcholedochal). These two forms of evaluation are explained below:

1. Intraoperative Cholangiography (IOC)

Although an IOC can be performed with plain radiography, dynamic fluoroscopy is strongly recommended given its usefulness in exploring the common bile duct. Studies also suggest that it can be more efficient and accurate.

- The IOC must be carefully inspected to evaluate the entire biliary tree. Specifically:
- Cystic duct: length, tortuosity, caliber, insertion point into the cystic duct.
- Common bile duct: caliber, leak, obstruction, filling defects (stones vs. air), contrast flow into the duodenum.
- Common, right, and left hepatic ducts: caliber, leak, obstruction, filling defects (stones vs. air), visualization of bifurcation, aberrant sectional right duct anatomy (14).

Nevertheless, according to Haggerty et al (14), it is important to identify the right ductal anatomy during IOC due to the variability of the sectional ducts. The right anterior sectional duct (segments 5 and 8) and the right posterior sectional duct (segments 6 and 7) must be identified separately. Specifically, the right posterior sectional duct must be clearly defined, as its entry into the central biliary tree is variable and it can insert below the bifurcation, into the cystic duct, into the gallbladder, or into the left main bile duct, in addition to being vulnerable to injury during cholecystectomy. The failure to identify the right ductal structures should alert to aberrant anatomy or possible biliary injury. If the presence of stones is suspected when the IOC shows a radiolucent defect, a meniscus, biliary tree dilation, or inability of contrast to enter the duodenum.

Similarly, Haggerty et al (14) indicate that laparoscopic common bile duct exploration is an established procedure that offers the potential to provide single-stage management for patients with choledocholithiasis. It presents a safety profile comparable to ERCP with laparoscopic cholecystectomy, in addition to offering lower costs and shorter hospital stays. Transcystic common bile duct ultrasound (TCBDUS) is a safe procedure, accessible to most general surgeons who frequently perform cholecystectomies. While transcystic common bile duct ultrasound (TCBDUS) offers greater efficacy for stone removal and access to the entire biliary tree, it is associated with higher complication rates compared to transcystic exploration and requires more advanced skills.

2. Laparoscopic Ultrasound

Laparoscopic ultrasound, according to Haggerty et al (14), explains that laparoscopic ultrasound can be performed instead of IOC to determine biliary anatomy, including duct size, stone characteristics, and ampullary and pancreatic head abnormalities that may affect the procedure. The confluence of the right and left hepatic ducts can be observed, as well as the junction of the cystic duct with the common bile duct. The common bile duct is followed to the duodenum to evaluate choledocholithiasis.

Benefits in Anatomical Identification Through the Use of Fluorescence and Prevention of Biliary Injuries in Laparoscopic Surgery

Among the benefits in anatomical identification through the use of fluorescence, as pointed out by López & Velásquez (1), ICG is a tricarbocyanine dye, characterized by being a green lyophilized powder, soluble in water. Some of the most important properties of this substance are that it is not pharmacologically active, not toxic, has no known metabolites, and the risk of administering this medication is minimal, as few adverse reactions have been reported.

However, Ankersmit et al; Baladrón González (15,16) explain that this substance, upon intravenous injection, immediately binds to plasma proteins (albumin), so it remains within the vasculature throughout its circulation. It has exclusively hepatic excretion through bile, avoiding enterohepatic recirculation. The elimination process is through passive uptake (concentration gradient) from the blood into the hepatocytes, which actively eliminate it into the bile canaliculi.

The clearance rate, as mentioned by López & Velásquez (1) citing Reinhart, Huntington, Blair, Heniford, and others, indicates that ICG is 18 to 24% per minute in the liver. The dye is cleared from the body exponentially in the first 20 minutes after its application, with a half-life of 3 to 4 minutes. After this period, the clearance rate decreases, and the compound remains in the plasma for more than an hour. The elimination rate of the dye is directly proportional to its concentration. These characteristics allow for multiple injections of the compound during the same procedure.

In relation to fluorescent cholangiography with indocyanine green, López & Velásquez (1) point out that it reports advantages over rescue surgical techniques and over intraoperative methods such as traditional intraoperative cholangiography, such as reduced costs and personnel needed, absence of radiation exposure, reduced surgical time, and technical facilities that allow multiple applications during the same procedure, becoming an ideal method in the prevention of iatrogenic biliary tract injuries.

Conclusions

It can be concluded that the administration of indocyanine green (ICG) fluorescence in laparoscopic surgery is of great utility, being an efficient method that helps in the precise real-time visualization of anatomical structures of the bile ducts, cystic duct, and blood vessels, allowing to reduce the probability of accidental injuries in the biliary tree and other surrounding tissues. Within the surgical process, it allows the surgeon to perform dissection precisely and avoid iatrogenic injuries, due to the identification of anatomical structures, preventing complications during surgery.

Regarding the benefits of using indocyanine green (ICG) fluorescence in laparoscopic surgery for the prevention of biliary injuries, it is characterized by being a safe technique, because structures are identified through a laparoscopic camera, where biliary anatomy can be precisely observed, minimizing the probability of errors during the surgical intervention. Another advantage of this type of surgical procedure is that, as it is a minimally invasive procedure, the patient recovers more quickly, because they experience less pain and the probability of infections is reduced. Even ICG is a useful tool for sentinel lymph node mapping, allowing the identification of metastases.

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