Intraoperative laparoscopic ultrasound during laparoscopic myomectomy: a narrative review

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Abstract

Intraoperative laparoscopic ultrasound (IOLUS), a dynamic imaging technique, has emerged as a valuable instrument for guiding surgery in various medical specialties. As IOLUS provides accuracy, improved visualization, and real-time guidance, the integration of IOLUS into many surgical procedures has occurred and IOLUS assists surgeons during advanced procedures. Today, laparoscopic myomectomy has become a prominent surgical procedure in gynecology. Despite its benefits, laparoscopic myomectomy presents certain challenges. The risk of residual fibroids is higher in laparoscopic myomectomy compared to abdominal surgery. The limited depth perception and restricted range of motion can also be obstacles for surgeons, especially when dealing with deeply embedded fibroids. IOLUS has the potential to overcome these limitations. In this study, our aim was to conduct a review of the literature concerning the use of IOLUS during laparoscopic myomectomy. (J Turk Ger Gynecol Assoc. 2024; 25: 179-83)

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Introduction

Laparoscopic myomectomy has gained prominence as a surgical procedure in the field of gynecology. In contrast to traditional open surgery, laparoscopic myomectomy presents several advantages, such as minimized scarring, shorter hospital stays, and a faster postoperative recovery (1). However, despite its benefits, laparoscopic myomectomy does present certain challenges. Laparoscopic myomectomy is considered an advanced laparoscopic surgery, especially in cases with many fibroids. The challenges include the need to find multiple myomas, potential use of many laparoscopic sutures, longer surgery time, and a higher risk of bleeding. These factors collectively categorize laparoscopic myomectomy as a complex laparoscopic surgical procedure (2).

Intraoperative laparoscopic ultrasound (IOLUS) is an imaging technique that involves the use of an endoscopic ultrasound probe, enabling real-time visualization of internal structures. IOLUS provides high-resolution images that assist surgeons in navigating anatomical structures (Figure 1). Throughout its history, IOLUS has undergone refinement, including improvements in image quality, probe design, and integration with laparoscopic instruments. IOLUS has established itself as a valuable tool, enhancing the precision and outcomes of surgeries across various medical specialties. When faced with challenges related to limited depth perception and restricted range of motion, IOLUS can provide a solution, ultimately improving the effectiveness of the procedure. Today, IOLUS is a cornerstone in general surgery, with surgeons using it for the precise localization of tumors, mapping, and assessing tumor invasion in the diagnosis and treatment of various diseases (3). In a study published by Wakelin et al. (4) in 2022, which involved 36 patients and compared computerized tomography (CT), endoscopic ultrasound, and IOLUS in the preoperative staging of esophago-gastric carcinoma, IOLUS was also notably superior to CT in the assessment of distant metastases. The

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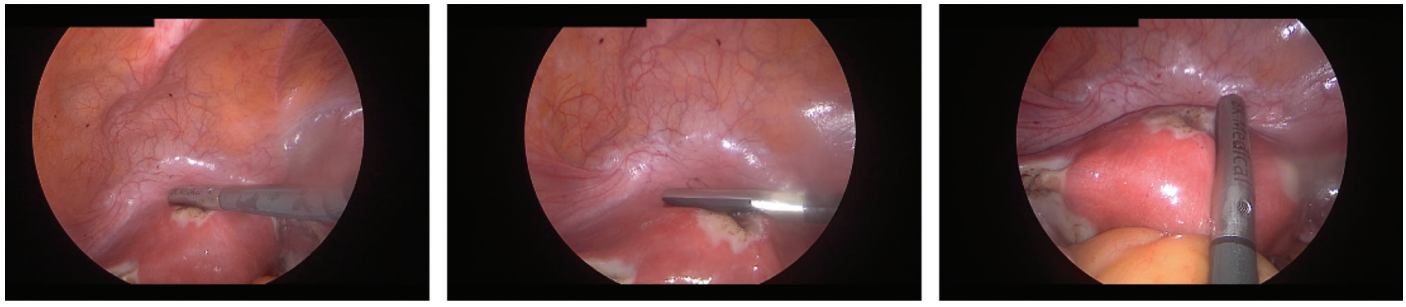

Figure 1. Intraoperative laparoscopic ultrasound during laparoscopic myomectomy surgery

reported sensitivity of IOLUS in detecting liver lesions can reach 100% (3). In urology, IOLUS helps surgeons accurately locate renal tumors and navigate delicate structures, ensuring maximal tumor removal while preserving kidney function (5).

The first use of IOLUS in laparoscopic myomectomy was described in 2004 (6). During laparoscopic myomectomy, once the telescope and instruments are in position, the IOLUS probe is introduced through a separate port. On the sterile handle of the IOLUS, there are buttons designed to control the movement of the probe's head, enabling adjustments in two planes. The maneuverability of the probe allows surgeons to guide it effectively, providing real-time ultrasound images on their monitor. This aids in visualizing internal structures, accurately locating fibroids, and assessing their features. IOLUS's interactive nature ensures that surgeons can adapt their approach based on live feedback from the ultrasound images.

There is a limited number of studies in the literature about IOLUS during laparoscopic myomectomy. The objective of this study was to perform a narrative review of the available literature regarding the application of IOLUS during laparoscopic myomectomy.

Materials and Methods

In this narrative review, an extensive literature search was performed using the PubMed database to identify pertinent studies related to IOLUS in the fields of gynecology, general surgery and urology. The search employed keywords such as "IOLUS," "gynecology," "general surgery," and "myomectomy." It was restricted to articles published exclusively in the English language.

History of IOLUS

The history of IOLUS can be traced back to the evolution of endoscopy and ultrasound technologies (7). During the 1960s, intraoperative ultrasound (IOUS) using A-mode or non-real-time B-mode imaging began. However, it was not widely adopted due to image interpretation challenges. In the late 1970s, special probes for surgery were developed. By the 1980s, IOUS became common in various surgical fields worldwide, especially hepatobiliary and pancreatic surgery. After 1990, as surgical techniques advanced towards minimally invasive approaches, the concept of real-time ultrasound imaging during surgery emerged. This led to the development of IOLUS, where the ultrasound probe could be used to guide surgical procedures and provide immediate feedback to the surgeon. While being an older technique, the initial use of IOLUS in laparoscopic myomectomy was documented in a case report in 2004 (6). In this case, a laparoscopic ultrasound transducer helped with the identification and accurate location of a myoma within an otherwise seemingly normal uterus.

Advantages of IOLUS-assisted laparoscopic myomectomy

The use of IOLUS for laparoscopic myomectomy offers a range of benefits in gynecological surgery. These benefits result from the real-time imaging and precision that IOLUS affords during the procedure.

IOLUS provides a clear and magnified view of the surgical field, allowing surgeons to identify location, size, and depth of fibroids with greater accuracy. This information is crucial for planning the best approach to removal. Especially deeply embedded or hard-to-see fibroids become more accessible with IOLUS guidance (8). In a recent study by Patel et al. (9), laparoscopic ultrasound was performed to examine 42 patients. This approach revealed 54 additional fibroids in 27 patients (64%), averaging two extra fibroids per patient. The median size of fibroids detected was 1.5 centimeters, with the majority being FIGO grade 3 (43%) and grade 2 (33%). This study underscores the value of IOLUS in identifying smaller intramural fibroids, particularly in patients with multiple fibroids. Urman et al. (8) documented 17 cases of symptomatic, deep, intramural myomas that remained unseen during laparoscopy. These myomas were successfully identified and removed using IOLUS during laparoscopic myomectomy without any complication. In another study comparing IOLUS with intraoperative transvaginal ultrasound, it was shown that IOLUS was better at detecting residual fibroids, although both methods are effective (10). In this study, 78 women underwent laparoscopic myomectomy. In this context, IOLUS identified a total of 140 residual fibroids,

whereas transvaginal ultrasound detected 127 (p=0.03). In a comprehensive study, IOLUS was compared with transvaginal ultrasound and magnetic resonance imaging (MRI) (11). The study involved 135 women who had symptomatic myomas and underwent laparoscopic ultrasound-guided radiofrequency volumetric thermal ablation of the myomas. IOLUS effectively detected a total of 818 myomas (mean 6.1 per subject, standard deviation 4.9), which was nearly twice the number of myomas compared to transvaginal ultrasound and 1.5 times more than MRI. As a result, IOLUS demonstrated its superiority by detecting the greatest number of myomas when compared to transvaginal ultrasound or MRI.

A distinctive benefit of IOLUS, unlike other imaging methods, is its capability to facilitate therapeutic interventions within the same session. It is acknowledged that the risk of residual fibroids is higher in laparoscopic myomectomy compared to abdominal surgery (12). However, IOLUS appears to be promising in addressing this issue. In a randomized controlled trial conducted with 156 patients divided into three groups, the recurrence rate was notably lower in the IOUES-guided laparoscopic myomectomy group compared to both the standard laparoscopic and open resection groups ($p<0.01$ in both cases) (13). Additionally, the IOLUS-guided group exhibited a lower residual rate than the standard laparoscopic group ($p<0.05$). However, there were no significant differences in residual rates between the IOLUS-guided group and the open resection group ($p>0.05$). Hence, IOLUS has the potential to identify additional fibroids, improve the outcomes of laparoscopic myomectomy, and decrease the occurrence of residual fibroids and recurrence rates. It should be noted that in certain cases, the presence of a significant number of myomas may lead to a preference for open surgery. This situation is regarded as a "relative contraindication" for laparoscopic myomectomy. However, the ease of intraoperative identification of myoma locations with IOLUS and the reduced risk of residual myomas may mitigate this "relative contraindication".

IOLUS offers additional advantages. Employing IOLUS for precise incision placement and size can result in reduced operation time and enhanced cost-effectiveness in material usage. Some studies in the literature have mentioned an extension in operation duration following IOLUS use; however, this is attributed to the removal of additional residual myomas using IOLUS (9). When conducted by a experienced surgical team familiar with setup and device operation, the use of IOLUS does not result in longer procedure times compared to routine transvaginal ultrasound. Furthermore, IOLUS allows surgeons to navigate complex anatomical structures, ensuring thorough fibroid removal without unnecessary damage to surrounding tissues. The ability to detect potential complications, like excessive bleeding or damage to adjacent organs, during surgery allows for timely intervention. This can minimize postoperative complications and improve patient outcomes. Therefore, by combining the strengths of IOLUS with laparoscopic myomectomy, surgeons can offer patients a more effective and safer treatment option. There is currently a lack of literature on cost-effectiveness analyses related to the use of IOLUS. However, a study conducted by Donoghue et al. (14), focusing on the cost-effectiveness of IOLUS in suspected choledocholithiasis, sheds light on its economic aspects. The study revealed that the cost per use of IOLUS was lower compared to magnetic resonance cholangiopancreatography (£183 vs. £365, respectively), making it a cost-effective option. Moreover, IOLUS offered the added benefit of reducing hospital bed days and saving approximately 240 hours of magnetic resonance cholangiopancreatography imaging time. This study highlighted the potential economic advantages of IOLUS application, which warrants further investigation in gynecology.

Challenges of IOLUS-assisted laparoscopic myomectomy

While the integration of IOLUS with laparoscopic myomectomy offers significant benefits, several challenges and considerations demand attention. Firstly, the proper calibration and setup of IOLUS equipment are paramount for obtaining accurate images. Ensuring the availability of well-maintained equipment is essential for successful implementation. Furthermore, IOLUS necessitates supplementary equipment and personnel. Hospitals and surgical centers must allocate resources for training, maintenance, and support to ensure the seamless integration of this technology. Presently, IOLUS is only accessible in select clinics and has yet to fully realize its potential in the field of gynecology.

Using IOLUS during laparoscopy requires training and experience. Surgeons must become proficient in interpreting ultrasound images. For instance, when employing the probe on the front surface of the uterus, it generates an image similar to that of transvaginal ultrasound. However, when the surgeon performs the ultrasound on the back surface of the uterus, the resulting image becomes a mirrored version of the classical transvaginal ultrasound image. This could potentially lead to confusion during the surgical procedure. Surgeons must establish their orientation based on the endometrium. If a fibroid is seen between the probe and the endometrium on the ultrasound monitor and the probe is positioned on the back surface of the uterus, the fibroid is actually located on the posterior wall of the uterus. Surgeons need to adapt to this situation, making a learning curve essential for the effective use of IOLUS.

Determining which patients will benefit most from IOLUS-assisted laparoscopic myomectomy requires careful consideration. Factors such as fibroid size, location, and individual patient characteristics play a role in the decision-

making process. As an example, while IOLUS may not offer significant benefits in detecting a large sub-serosal fibroid with a clearly defined perioperative location, it presents distinct advantages in the removal of a fibroid embedded in the myometrium, suspected to contribute to bleeding or infertility, situated close to the endometrium, and whose location cannot be determined intraoperatively. While IOLUS can enhance surgical precision, it may slightly extend procedure duration. Therefore, balancing the benefits of enhanced accuracy with the need for efficient surgical workflow is crucial.

Future directions of IOLUS in gynecology

As ultrasound technology advances, the quality of IOLUS images is expected to enhance, providing surgeons with better visualization during interventions the integration of machine learning algorithms into IOLUS also holds promise for automated image analysis. Beyond its current application in laparoscopic myomectomy, IOLUS has a potential to broaden its scope to guide a spectrum of minimally invasive gynecological procedures. For example, in a video article published in 2023, the technique of laparoscopic shaving for rectosigmoid endometriosis during deep endometriosis surgery was demonstrated (15). This technique employs a novel approach involving laparoscopic ultrasound guidance to facilitate thorough excision. Another area where IOLUS could potentially be beneficial is in the treatment of isthmocele. One of the most significant challenges in laparoscopic isthmocele repair is identifying the location of the defect. In the literature, methods such as laparoscopic repair with hysteroscopy guidance and the use of a Foley catheter have been described to overcome this difficulty (16,17). However, due to its direct contact with the uterus, IOLUS can be used more easily than all these methods to identify the location of the isthmocele. Similarly, another potential application could involve the intraoperative diagnosis of adenomyosis in complex surgery, such as endometriosis surgery.

Conclusion

IOLUS has the potential to represent a significant advance in the field of gynecological surgery. By providing real-time imaging, enhanced visualization, and precise guidance, IOLUS assists surgeons in locating and removing “hard-to-find” fibroids. While challenges such as setup, the learning curve, and patient selection exist, the potential benefits outweigh these obstacles. As research and technology progress, IOLUS-guided procedures will offer patients safer, more effective, and minimally invasive treatment options. These findings are promising, but the evolution of IOLUS-assisted laparoscopic myomectomy is an ongoing process. Further research, larger-scale studies, and long-term follow-ups are essential to establish its place as a standard practice in gynecology.

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