European Journal of Obstetrics and Gynecology 302 (2024) 306–309

Contents lists available at ScienceDirect

European Journal of Obstetrics & Gynecology and Reproductive Biology

journal homepage: www.journals.elsevier.com/european-journal-of-obstetrics-and-gynecology-and-reproductive-biology

Review article

Enhancing precision in hysteroscopic surgery: The role of intraoperative ultrasound

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ARTICLE INFO

Keywords:
Gynecological ultrasound
Hysteroscopic surgery
Hysteroscopy
Intraoperative ultrasound
Uterine intracavitary pathology

ABSTRACT

Hysteroscopy stands as the gold-standard approach for managing intrauterine pathology. However, in complex clinical cases, hysteroscopic evaluation alone may prove insufficient for the safest and successful patient management. Intraoperative ultrasound (IOUS) has emerged as a valuable adjunct to hysteroscopic surgery, offering real-time visualization of endometrial cavity, uterine walls and instruments within the uterine cavity, enabling precise delineation of anatomical structures, and helping to assess the extent of pathology during intricate interventions. This review aims to comprehensively assess the applications, efficacy and utility of IOUS in hysteroscopic surgery.

Available evidence indicates that in hysteroscopic myomectomy, IOUS significantly reduces the risk of uterine perforation, particularly in submucosal FIGO 2 myomas, and enhances the likelihood of a single-step procedure. During hysteroscopic metroplasty, ultrasound guidance decreases the chance of incomplete uterine septum resection. In the hysteroscopic management of severe Asherman syndrome, IOUS reduces the risk of uterine perforation or false passage. For cesarean scar pregnancy (CSP), ultrasound is crucial in defining the most appropriate surgical approach and is effective in guiding the hysteroscopic treatment of endogenic CSP.

The use of IOUS in hysteroscopy proves valuable in complex cases where the risk of uterine perforation or incomplete procedure is increased.

Introduction

Hysteroscopy has revolutionized the field of gynecological surgery, allowing for the diagnosis and treatment of intrauterine pathologies with minimal invasiveness and optimized patient outcomes. Operative hysteroscopy stands as the gold-standard approach for the treatment of endometrial and uterine intracavitary lesions, such as endometrial polyps, submucous myomas, uterine septa, retained products of conception and intrauterine adhesions. This preference stems from its ability to provide direct intrauterine visualization, which enables precise surgical interventions [1]. However, for managing more complex conditions, such as the resection of submucosal FIGO type 2 myomas and the treatment of Asherman syndrome, relying solely on hysteroscopic evaluation may prove insufficient to ensure a safe and successful treatment [2,3]. Inadequate visualization can hinder the successful completion of the procedure and potentially expose patients to

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https://doi.org/10.1016/j.ejogrb.2024.09.027
Received 3 April 2024; Received in revised form 14 September 2024; Accepted 17 September 2024
Available online 19 September 2024

complications, such as uterine perforation [1,4]. In such challenging scenarios, intraoperative ultrasound (IOUS) can significantly enhance the efficacy and safety of hysteroscopic approaches, emerging as a valuable tool for improving outcomes [3,5,6]. IOUS provides real-time imaging-based guidance, enabling surgeons to better visualize and navigate intrauterine instruments, leading to improved diagnostic accuracy, patient safety, and therapeutic success [3,7]. This publication aims to review the applications of IOUS in hysteroscopic surgery and evaluate its utility in the treatment of different intrauterine pathologies.

Material and method

To conduct a non-systematic literature review, the authors searched 4 databases (MEDLINE, EMBASE, The Cochrane Library and Web of Science), using the keywords "intraoperative ultrasound" in conjunction with "hysteroscopy". The selection was restricted to the papers published in English, spanning from the inception of these databases up to September 1st, 2023. Titles and abstracts of the identified publications were analyzed by two authors (L.F.C. and I.S.) to select original studies and reviews that aligned with the project's objectives. Potentially eligible articles were retrieved (in full text) and independently assessed by the authors (L.F.C. and I.S. in the initial phase; D.D. in the subsequent phase). Of the 145 articles analyzed, 20 met the inclusion criteria (i.e., having a focus on IOUS in hysteroscopic surgery). The reference lists of these articles were also checked to obtain additional sources of information. Subsequently, relevant data were extracted from selected articles. Given the nature of our findings, our working group chose to conduct a narrative synthesis of the information extracted from the currently available literature.

Results

Evidence on the utility of IOUS during hysteroscopic myomectomy

Hysteroscopic myomectomy is the most commonly used minimally invasive procedure to treat intracavitary myomas [8]. The role of IOUS in the hysteroscopic management of submucosal myomas was addressed in 6 of the articles included in this review [2,9–13]. In 1995, Wortman et al. described an approach involving the use of abdominal and/or transrectal ultrasound (US) as an alternative to laparoscopy for guiding hysteroscopic myomectomy [9]. In line with this publication, IOUS makes the procedure even less invasive and reduces the risk of uterine perforations, whereas laparoscopy primarily confirms perforations that have already occurred, with a limited role in their prevention [9]. Some authors agree that IOUS facilitates the complete removal of the deep intramural portion of a myoma, offering reassurance during intrauterine resection [10]. Notably, in a prospective study by Korkmazer et al. involving 64 women, hysteroscopic myomectomy guided by abdominal US achieved complete myoma resection in all patients, with no instances of uterine perforations [2]. When the distance between the deepest part of the myoma and the serosa measures less than 5–8 mm, some authors advocate for routine US guidance during hysteroscopic myomectomy [11]. Nevertheless, contrasting viewpoints state that the minimal distance between myoma and serosa (also called "myometrial free margin" in literature) should not serve as a determining factor. This perspective is supported by IOUS findings, which highlight the dynamic nature of this parameter and its potential to increase during the procedure. A 2011 study showed that the median myometrial free margin gradually increased from 5.4 mm (range 3.6–12.3 mm) on preoperative transvaginal US to 12.7 mm (range 10.4–17.5 mm) after complete fibroid resection [12]. Ludwin et al. conducted a prospective study involving 120 women who underwent hysteroscopic myomectomy, with or without transrectal IOUS guidance. The odds of successfully achieving a one-step complete resection were twice as high in the transrectal US-guided group compared to the control group [13].

Evidence on the utility of IOUS during hysteroscopic metroplasty

The use of US guidance in hysteroscopic treatment of uterine septa has also been subject of research and investigation. In a recent prospective study, Muzii et al. compared 19 consecutive patients with a septate uterus who underwent hysteroscopic metroplasty using 3D transvaginal IOUS to 19 control group patients that underwent the procedure without US guidance. The findings demonstrated that the use of 3D transvaginal IOUS significantly reduced the rate of incomplete metroplasty compared to the control group (0 % vs. 26 %, $p = 0.04$) [14]. These findings align with previous research in which 27 patients who underwent rectal US-guided metroplasty were compared to a control group where IOUS was not employed during the procedure. The feasibility of transrectal IOUS during hysteroscopic metroplasty was observed, indicating a potential enhancement in achieving complete resection of uterine septa without a concurrent increase in the risk of complications [15]. Compared to laparoscopically guided hysteroscopic metroplasty, US-guided hysteroscopic metroplasty is associated with shorter operating times, reduced postoperative hospital stays, a lower incidence of residual septum, and greater cost-effectiveness [16]. Furthermore, Kresowik et al. found that in the surgical repair of intrauterine septa, laparoscopy-guided hysteroscopy resulted in a higher rate of uterine perforation compared to transabdominal US guidance [3].

Evidence on the utility of IOUS during hysteroscopic resection of intrauterine adhesions

The surgical handling of Asherman syndrome has traditionally posed technical challenges. Myers and Hurst showcased the treatment of 12 patients with severe Asherman syndrome, emphasizing the indispensable role of IOUS in preserving optimal intracavitary visualization, particularly in cases with inadequate cavity distention and bleeding [17]. Tsui et al. adopted a similar approach to treat severe Asherman syndrome in four infertile patients, achieving successful outcomes without uterine perforations. All treated women successfully conceived after the procedure [18]. In another study focused on the surgical management of severe Asherman syndrome, IOUS emerged as a pivotal tool in detecting false passages within the uterine wall, especially in complex cases characterized by challenging access to the uterine cavity. Among 463 US-guided hysteroscopic resections performed for Asherman syndrome, a singular case of perforation and five instances of false passage were documented [19].

Evidence on the utility of IOUS in other hysteroscopic procedures

Cervical stenosis may make hysteroscopic surgery impracticable and it inevitably increases the risk of false passage, cervical laceration and uterine perforation. Salari et al. demonstrated the utility of IOUS in managing cervical stenosis by employing it to guide the insertion of a catheter through the cervical canal and into the uterine cavity. This catheter served as a guide for the hysteroscopic morcellator, ensuring safe placement into the uterine cavity and reducing the risk of uterine perforation and false passage [20].

Additionally, the morphological assessment and classification of the cesarean scar niches and cesarean scar pregnancy (CSP), as well as the choice of treatment, are currently based on the use of US [21,22]. Cesarean scar niche is identified on US as an indentation at the cesarean defect scar, with a depth of at least 2 mm [22]. In a study involving 61 patients with secondary infertility, hysteroscopic niche resection showed superior clinical pregnancy rates compared to expectant management [23]. The appropriate surgical approach for CSP depends on its type (I, II or III), assessable through US. Hysteroscopy, preferably US-guided, may be considered for endogenic CSP (*i.e.*, type I with a residual myometrium thickness >3 mm), while laparoscopy is recommended for exogenic CSP (*i.e.*, type II or III) [21]. Li et al. analyzed the hysteroscopic treatment of CSP, categorizing patients into three groups based

on their treatment history: US-guided hysteroscopic removal (*i.e.*, IOUS), methotrexate combined with hysteroscopy and uterine arterial embolization (UAE) combined with hysteroscopy. Using B-mode US, the authors conducted hysteroscopic removal until no residual pregnancy tissue was detected, demonstrating its effectiveness and cost-efficiency. However, this approach showed a higher risk of bleeding compared to the UAE group [24]. Another study provided evidence supporting the utility of US-guided hysteroscopy in selecting the most suitable approach for the surgical treatment of persistent CSP [25].

Literature summary and discussion

US holds a significant role in gynecology, enabling both diagnosis and monitoring of various gynecological conditions [26]. Initially introduced in 1961 to aid in diagnosing renal calculi, IOUS has garnered extensive use across varied surgical scenarios [27,28]. Within gynecology, it offers real-time imaging capabilities during procedures such as intrauterine device removal, dilatation and curettage, laparoscopy, and hysteroscopy [7]. In laparoscopy, IOUS enhances the accuracy of myomectomy and ovarian cyst excision by compensating for the lack of direct tissue palpation and aiding in the precise preservation of normal ovarian tissue through the delineation of the wedge resection [29–31]. In hysteroscopy, IOUS has been promising to improve the treatment of complex intracavitary pathology, including submucosal myomas with a notable intramural component, severe Asherman syndrome and uterine septa [3,7]. The insertion of dilatators preceding hysteroscopy, when cervical dilatation is required, may also be guided by US, ensuring accurate alignment with the cervical canal and reducing the risk of perforation or false passages [20,32].

In certain studies, laparoscopy served as an alternative guide instead of US for operative hysteroscopy. Nevertheless, US had the advantages of being simpler, non-invasive and cheaper [16]. Additionally, studies suggest that laparoscopy-guided *vs.* US-guided hysteroscopic interventions may course with increased relative risk of uterine perforation, as myometrium cutting depth is more readily discernible through US compared to laparoscopy [3].

In a previous review on IOUS and hysteroscopy, Jayaprakasan and Ojha emphasized the expanding role of US as a real time-guide in reproductive medicine and surgery, including hysteroscopic resections of uterine septa and fibroids, as well as the treatment of intrauterine adhesions [7]. The authors underscored the potential benefits of US guidance in intrauterine procedures, revealing a trend towards reduced perforation rates and more cost-effective approach compared to laparoscopic guidance [7]. In another review, Grewal et al. concluded that while the consistent identification of additional pathological information with IOUS remains uncertain, the well-documented benefits of IOUS in aiding surgeons to prevent complications and achieve precise incision placement in endoscopic procedures are firmly established [33].

Most studies analyzed utilized the transabdominal route for IOUS in hysteroscopy due to its practicality as a guidance tool during these procedures [2,3,5,10,12,16–20]. A moderately filled bladder is recommended for optimal visualization of the uterus and cervix with the transabdominal probe [7]. However, the lower frequency of transabdominal US results in reduced resolution and precision. While transvaginal US offers higher accuracy, its use may interfere with hysteroscope insertion and maneuvers, requiring alternation between the US probe and the hysteroscope [14,34]. Transrectal US has emerged as an alternative, compensating for the limitations of other US routes in hysteroscopic surgery [14]. To facilitate hysteroscope maneuvers within the constrained working field shared by the surgeon and the sonographer, some authors recommend intermittent use of the transrectal probe during crucial stages of surgery, rather than employing transrectal US throughout the procedure [13].

Advances in operative techniques and the surgeon's expertise allow for the hysteroscopic treatment of submucosal myomas with substantial intramural involvement (FIGO type 2) [35]. Techniques such as monopolar or bipolar resectoscope and hysteroscopic morcellation are commonly used for managing these fibroids [2,10]. However, assessing critical anatomical parameters, such as myometrial free margin thickness, remains challenging with conventional hysteroscopy, potentially elevating the risk of uterine perforation [13]. Our analysis revealed that IOUS played a pivotal role in accurately localizing the electrode relative to the myoma, myometrium, and uterine serosa. It also enabled real-time monitoring of myometrial thickness changes during hysteroscopic myomectomy, significantly expanding the safety margin [2,10,12]. This approach holds potential to prevent complications like bowel injury, improve the rate of complete myoma resections and reduce the need to stop the procedure due to uterine perforation [7,13]. Some researchers suggest that IOUS is particularly beneficial for managing type 2 myomas, where visualization and removal are more challenging compared to type 0/1 myomas, which protrude significantly into the uterine cavity. Additionally, IOUS may play a crucial role in guiding the hysteroscopic management of type 3 myomas, characterized by its complete intramural development while encroaching the endometrium [36,37]. In such cases, IOUS aids in pinpointing the optimal incision sites within the uterine wall [13]. By augmenting the feasibility of performing a single-step hysteroscopic myomectomy, IOUS may reduce overall treatment costs and the inconvenience associated with multiple-step hysteroscopic procedures [2,12,13].

Hysteroscopic metroplasty is the preferred method for correcting uterine septa, yet consensus on its optimal management remains unclear [38,39]. The main challenge is determining when the procedure is complete, as incomplete resection/residual septum may impact future reproductive outcomes [7,14,40]. Even when typical surgical endpoints are met, such as the hysteroscope moving freely from one cornual recess to the other or simultaneous visualization of both tubal ostia, residual septum may still be present in 4–44 % of cases [41,42]. Conversely, extending the procedure beyond the ideal limit may lead to uterine perforation or an increased risk of uterine rupture in future pregnancies [14]. Our review found that IOUS, including 3D US, has been proposed to reduce these risks by improving visualization of the septum and aiding in a complete resection [14,15]. However, given the small sample size in existing the studies, these recommendations should be interpreted with caution.

Severe cases of Asherman syndrome, characterized by extensive uterine cavity obliteration, make hysteroscopic visualization challenging due to poor cavity distention [3,43]. In such instances, IOUS guidance is crucial for safe dilation of the cervix and endometrial cavity, as well as for guiding the hysteroscopic dissection within the appropriate tissue planes [3,17,19]. The studies analyzed showed that IOUS was effective in reducing cases of uterine perforations or false passage. Several authors have reported that IOUS enables surgeons to proceed safely and complete the dissection, even in situations where continuing the procedure solely though hysteroscopy may pose risks [3,7].

The emphasis on IOUS in hysteroscopy should focus on conducting randomized clinical trials to evaluate its influence on surgical outcomes, patient safety and postoperative recovery in various hysteroscopic interventions. Additionally, efforts should aim to develop evidence-based clinical guidelines for the integration of IOUS in hysteroscopic procedures, providing recommendations for its optimal use in different clinical scenarios. The inclusion of US training programs for hysteroscopic surgeons is imperative to ensure competence in IOUS.

Conclusion

US can be considered an affordable and non-invasive approach for examining pelvic organs before, during and after surgery. The transabdominal or transrectal routes are notably preferred methods for guiding hysteroscopic interventions with US. Routine application of IOUS in hysteroscopic surgery may not be imperative, considering that many procedures can be effectively executed via direct hysteroscopic

visualization of the intrauterine cavity without complications. However, IOUS presents as a valuable adjunct, particularly in complex cases where the risk of uterine perforation or incomplete lesion resection is heightened. In these difficult scenarios, IOUS guidance emerges as a crucial and suitable tool, offering added precision and aiding surgeons in achieving optimal outcomes.

Funding

None.

CRediT authorship contribution statement

Luís Ferreira de Castro: Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Inês Santos:** Writing – review & editing, Methodology, Data curation. **Antonio Simone Laganà:** Writing – review & editing. **Bart de Vree:** Writing – review & editing. **Bruno J. van Herendael:** Writing – review & editing. **Dusan Djokovic:** Writing – review & editing, Supervision, Methodology, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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