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Improving efficacy and safety of surgery in benign gynaecology: the case for indocyanine green

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ABSTRACT

Indocyanine green (ICG) with near-infrared imaging is a valuable adjunct in minimally invasive gynaecological surgery, enhancing anatomical visualisation and surgical precision. This narrative review synthesises current evidence on ICG's clinical applications, safety, and practical implementation in benign gynaecology. ICG supports bladder and ureteric identification, cavity integrity checks, and assessment of bowel and ovarian perfusion. It also aids detection of endometriosis lesions, though diagnostic accuracy remains variable. ICG is safe and feasible, with growing evidence supporting its role across a range of procedures. Further research is needed to standardise protocols, assess cost-effectiveness, and support broader adoption in clinical practice.

Keywords: Fluorescence imaging, ICG, indocyanine green, ureteric identification, perfusion, surgical safety

Introduction

Indocyanine green (ICG) is a versatile compound with a well-established safety profile and growing applications in minimally invasive surgery, particularly for assessing vascular perfusion and visceral integrity.[1,2] When illuminated with near-infrared (NIR) light, ICG emits infrared fluorescence, detectable by specialised imaging equipment. The introduction of NIR imaging with laparoscopic and robotic cameras has accelerated the adoption of ICG in minimally invasive surgeries. This paper aims to consolidate the growing body of evidence on ICG in benign gynaecology and provide practical guidance for its safe use, addressing the current lack of comprehensive, clinically focused reviews on the topic. By doing so, we seek to increase user confidence, reduce intra-operative complications, promote earlier recognition of injuries, and prevent severe long-term sequelae. Practical techniques for safely integrating ICG into practice will also be detailed, highlighting its potential to improve surgical outcomes.

Methods

Study Design

A comprehensive literature review was conducted to evaluate the clinical applications, efficacy, and safety of ICG in benign gynaecological surgery. The study synthesised data from clinical trials, systematic reviews, feasibility studies, and case reports to assess ICG's role in improving surgical precision, reducing complications, and enhancing anatomical and pathological detection.

Search Strategy and Data Sources

A systematic search of the literature was performed using databases such as PubMed, Embase, and Cochrane Library. The search included peer-reviewed

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articles using a combination of Medical Subject Headings and keywords related to "Indocyanine Green," "ICG fluorescence," "benign gynaecology," "laparoscopic surgery," "robotic surgery," "endometriosis," "tubal patency," "ureteric injury," and "vascular perfusion."

Inclusion Criteria

Studies on ICG in benign gynaecological procedures were included, encompassing various research types such as trials, case reports, and reviews. These studies evaluate its effectiveness, safety, and feasibility in surgery, with a focus on surgical precision, anatomical identification, blood flow, and complication rates.

Exclusion Criteria

Studies exclusively focused on gynaecological oncology, non-English articles without translation, reviews without original data, and research lacking clear outcome measures were excluded.

Data Extraction and Analysis

The extracted data included study design and sample size, the type of benign gynaecological procedure performed, and details on dosage, route of administration, and imaging techniques used. Outcomes assessed encompassed efficacy in anatomical identification, complication rates, surgical precision, safety, diagnostic accuracy, and postoperative recovery.

Limitations and Biases in Study Methodology

A narrative synthesis of the findings was performed, categorising results by the specific surgical application of ICG, including bladder demarcation, ureteric identification, bowel and ovarian perfusion assessment, tubal patency testing, and endometriosis lesion detection.

Indocyanine Green Administration Protocols

Standardised ICG dosing and administration techniques were identified from the literature and summarised in Table 1. The protocols included intravenous, intrauterine, intravesical, intravaginal, and intra-fibroid injection methods. The primary objective was to provide practical guidance for clinicians to ensure consistent and safe application of ICG in benign gynaecological surgery.

Ethical Considerations

As this study involved a review of existing literature, no ethical approval was required. However, ethical considerations from the included studies were reviewed to ensure compliance with international clinical research standards.

Results

ICG has versatile applications across various surgical disciplines, including hepatopancreatobiliary, colorectal, cardiac, ophthalmic, and gynaecological oncology surgery.[1,3] Once administered intravenously, ICG remains largely unmetabolised and undergoes rapid hepatic clearance by liver parenchymal cells into bile. Studies indicate that approximately 95% of intravenously administered ICG remains plasma-bound, allowing it to stay predominantly within the intravascular compartment. This property minimises its absorption and impact on surrounding tissues, making it an effective and safe tool for intraoperative imaging.[4]

ICG is generally accepted as a safe, non-toxic substance, with approval from international regulatory bodies for use in medical diagnostics.[5,6] Adverse effects are rare. In a prospective study involving 1,226 patients, only five cases of moderate to severe reactions were reported, and no deaths were associated with ICG administration.[7] These reactions included non-fatal anaphylaxis and urticaria, which were promptly recognised and treated without long-term consequences. The primary precaution with ICG administration is to avoid its use in patients with known iodide allergies.[6]

ICG is manufactured as a dry powder, typically distributed in 25 mg vials, and reconstituted in sterile water to create a 2.5 mg/mL solution. This solution can be administered via various routes, such as intravenous. Once prepared, the solution remains stable for use throughout the operative day. However, when exposed to daylight at room temperature, its fluorescence intensity declines by 8–16% per day during the first three days. To maintain maximum efficacy, ICG solutions should be stored at low temperatures (approximately 4 °C) and protected from light. Due to spectral instability, ICG should only be dissolved immediately before use.

Intravenous administration of ICG to assess tissue perfusion and viability typically involves a dose of 2.5 mg per bolus, administered slowly to minimise the risk of adverse reactions. Due to ICG's hepatic clearance, lower doses are preferred for patients with impaired liver function. In healthy individuals, ICG has a half-life of approximately 3–4 minutes, with rapid clearance from the bloodstream within 15–20 minutes via the liver and excretion into bile. This quick clearance makes ICG ideal for procedures requiring immediate vascular imaging or perfusion assessment, as it provides real-time information without lingering effects.[6] Additionally, the rapid half-life enables repeated dosing without the risk of false positives.

For similar applications, intravenous methylene blue has been explored. However, methylene blue is associated with greater adverse effects and false negatives due to its metabolite, leukomethylene blue, being colourless.[5,8] This further underscores ICG's superiority for real-time vascular and perfusion imaging.

Clinical Uses of Indocyanine Green

ICG is a well-established technique for sentinel lymph node detection in gynaecological oncology, as demonstrated in the landmark FILM trial, which identified ICG as superior to methylene blue due to its high uptake and enhanced visualisation in laparoscopic procedures.[3] In addition to its superiority over methylene blue, ICG has also demonstrated superior detection rates when compared with technetium-99m (Tc99m) with methylene blue dye. In a meta-analysis by Baeten et al.[9], ICG was associated with significantly higher bilateral sentinel lymph node detection rates compared to Tc99m (88.6% vs 76.5%, $P<0.001$), supporting its emerging role as a preferred tracer in minimally invasive sentinel lymph node mapping procedures. Beyond sentinel lymph node detection, ICG has been explored in a variety of experimental applications, including assessing vaginal cuff perfusion, identifying nerves during nerve-sparing radical hysterectomies, and evaluating the viability of flap reconstructions in vulval cancer.[10,11] Although these methods are limited to small-scale case series and reports, they highlight the broad potential scope of ICG in advancing surgical practice.

With laparoscopic and robotic approaches now the preferred methods for abdominal surgery in benign gynaecological cases, ICG has emerged as an invaluable tool for demarcating key anatomical structures, minimising intra-operative complications and ultimately expediting recovery and reducing adverse surgical outcomes. Numerous case reports, case series, and video publications have demonstrated the use of ICG in benign gynaecology. However, there remains limited guidance and consensus on its use. Current applications include:

- **Demarcating the bladder and assessing bladder wall integrity:** Particularly useful post-hysterectomy or during complex surgeries to avoid injury.

- **Ureteric identification and vascularity assessment:** Enhances safety during pelvic dissections.

- **Identification of the uterine cavity and integrity assessment:** Post-myomectomy or adenomyomectomy.

- **Delineation of vaginal mucosa:** Improves precision in vaginal surgeries.

- **Assessing tubal patency:** Facilitates minimally invasive evaluation of fallopian tube function.

- **Assessing bowel perfusion in complex endometriosis surgery:** Ensures vascularised anastomoses and reduces complications.

- **Assessing ovarian perfusion in acute torsion:** Aids in determining ovarian viability and guiding surgical decisions.

- **Identification of endometriotic implants:** Enhances visualisation of diseased tissue during excision procedures.

These examples underscore ICG's growing role in benign gynaecology, though further research and standardised guidelines are needed to optimise its application

Demarcating the Bladder and Assessing Bladder Wall Integrity Post Hysterectomy/Complex Surgery

The incidence of bladder injury during laparoscopic hysterectomy is estimated to be 0.02–0.7%,[12] often occurring when the posterior bladder dome is reflected from the lower uterine segment during development of the utero-vesical (UV) fold prior to colpotomy. Adhesions at the UV fold are common following caesarean sections. Studies report adhesions in approximately 24% of patients after one caesarean delivery and up to 83% after three caesarean deliveries,[13] adding technical challenges and increasing the risk of urinary tract injury during hysterectomy.

With the increasing incidence of caesarean deliveries and adhesions, intra-operative ICG fluorescence serves as a crucial adjunct to safe surgical practice by clearly demarcating the bladder edge, enhancing the surgeon's confidence, and reducing the risk of bladder injury (Figure 1a). This is achieved by diluting 25 mg of ICG into 200 mL of sterile water and instilling the required volume into the bladder via a urinary catheter and bladder syringe (Table 1).

Historically, cystoscopy or bladder inflation with saline or methylene blue dye has been used to assess bladder injury. However, saline is colourless and may fail to detect small leaks, while methylene blue can disrupt visual clarity, particularly in cases of leakage. In contrast, ICG fluoroscopy provides superior visualisation, as the

NIR light can be turned off as needed[14-17] and avoids unwanted staining of the pelvic cavity. Yoshida Ueno et al.[15] have standardised the 'ICG-washout' technique (where instillation and subsequent drainage of ICG from the bladder allows for improved identification of the bladder dome) ensuring adequate safety margins during colpotomy. Additionally, real-time ICG fluorescence has been successfully applied in the robotic excision of bladder wall endometriosis, facilitating precise resection while preserving uninvolved bladder tissue.[16] A further case report described ICG-guided bladder nodule shaving in deep infiltrating endometriosis (DIE), demonstrating how fluorescence imaging can assist in delineating the nodule and ensuring complete excision with minimal collateral damage.[17]

Delineation of Vaginal Mucosa

Intravaginal dye is a well-established technique for highlighting the edges of the vaginal mucosa to ensure precise vault closure, with studies estimating a reduction in dehiscence rates by 0.64%–1.35%.[18] This technique is particularly valuable not only for vault closure but also in cases requiring resection of full-thickness endometriotic nodules (Figure 1b). While methylene blue has traditionally been used for this purpose, ICG offers a safe and cost-effective alternative that enhances visualisation during laparoscopic surgery by providing superior fluorescence under NIR light (Table 1).

Menezes and Rao[19] demonstrated that vaginal ICG application can effectively delineate the rectovaginal plane in patients with distorted pelvic anatomy, significantly improving real-time anatomical visualisation and easing surgical navigation during complex endometriosis surgery.

Sarofim et al.[20] replaced traditional tactile guidance during laparoscopic sacrocolpopexy with direct injection of ICG into the vaginal walls to identify optimal dissection sites on the anterior and posterior compartments. Fluorescence imaging enabled precise localisation without the need for vaginal manipulation or tactile cues, simplifying the procedure and supporting future robotic adaptations.[20]

A further novel application of ICG was recently described by Khazali et al.[21] In this case, an endometriotic vaginal nodule was 'tattooed' with ICG by injecting 1 mL of a 2.5 mg/mL ICG solution (prepared by diluting 25 mg of ICG in 10 mL of sterile saline) trans-vaginally into the vaginal mucosa just below the nodule margin. This technique allowed clearer visualisation of the nodule, facilitating precise excision while preserving normal vaginal tissue.

Identification of the Uterine Cavity and Assessing Integrity Post Myomectomy/Adenomyomectomy

A common concern with myomectomy is the potential risk of uterine rupture in subsequent pregnancies. Although rare, uterine rupture is associated with significant maternal and foetal mortality. Further studies are needed to determine intra-operative factors influencing the risk of rupture; however, the breach of the endometrial cavity during myomectomy is an important consideration. This factor should be addressed when counselling patients about the timing and mode of delivery in future pregnancies.[22] Intra-operative identification and repair of endometrial defects are therefore crucial to reduce the risk of complications.[23]

ICG is well absorbed by endometrial tissue but minimally by myometrium or fibroid tissue, effectively delineating the endometrial border and aiding in the prevention of cavity breaches during myomectomy. This also facilitates the identification and closure of small breaches. To

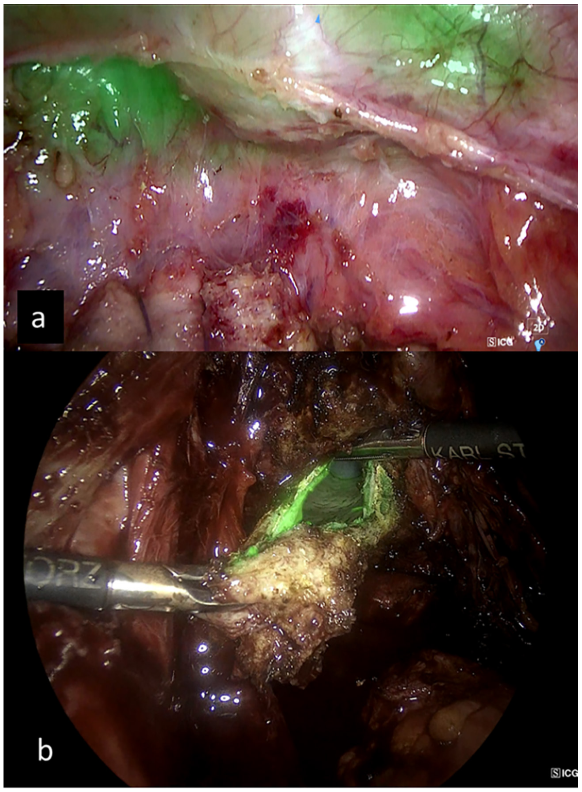

Figure 1. a) ICG instilled in the bladder following total laparoscopic hysterectomy to rule out bladder injury. b) Vaginal ICG to aid demarcation in a full thickness vaginal wall nodule resection.

ICG: Indocyanine green.

achieve this, ICG is injected through the cervix using a uterine manipulator or injector (Table 1). The ICG rapidly absorbs into the endometrial tissue, clearly marking the cavity. Any fluorescence leakage observed during the procedure or during a final inspection indicates a breach of the endometrial cavity, enabling prompt repair.[23]

Naem et al.[24] proposed a novel use of ICG during myomectomy. They hypothesised that injecting ICG directly into a myoma could help clearly delineate the borders of the pseudo capsule. This technique may facilitate easier identification of fibroid boundaries, enabling successful complete resection while minimising blood loss.[24]

Laparoscopic or robotic niche repair is a challenging gynaecological procedure with variable outcomes. Krentel et al.[25] described a novel use of ICG to clearly demarcate the uterine niche prior to laparoscopic surgery. The use of ICG eliminates the need for a secondary stack system and concomitant hysteroscopy. The authors highlight several benefits, including immediate niche visibility, the ability to clearly identify resection margins, and the avoidance of unnecessary adhesiolysis and tissue preparation. These advantages may streamline the procedure and improve surgical precision and highlighting yet another potential use of ICG.

Assessing Tubal Patency

The tubal dye test is a key component in evaluating subfertility and has traditionally been performed using methylene blue dye. ICG offers several advantages over methylene blue, enabling real-time visualisation of tubal patency through fluoroscopic transillumination. Unlike methylene blue, ICG can be administered prior to operative manipulation, reducing the risk of false negatives caused by tubal spasm (Figure 2).[21,26,27] Additionally, ICG remains transparent under normal lighting, avoiding unwanted staining of pelvic organs that could hinder the surgical procedure. The same technique is employed by injecting ICG through the cervix using a uterine manipulator or injector (Table 1).

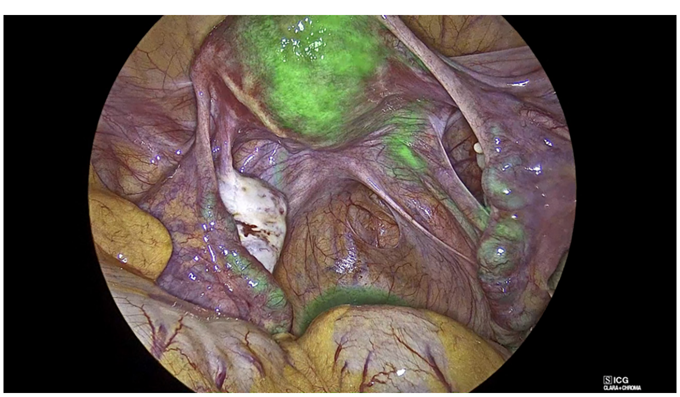

Figure 2. ICG tubal dye test prior to excision of endometriosis via uterine manipulator.

ICG: Indocyanine green.

Ureteric Identification and Assessment of Ureteric Vascularity

Although ureteric injuries during pelvic surgery are uncommon, they carry significant morbidity. Approximately 70% of iatrogenic ureteric injuries are not identified intra-operatively and are diagnosed in the post-operative period.[28] In gynaecological surgery, ureteric injuries are most likely to occur in cases of significant anatomical distortion, such as deep invasive endometriosis and cervical or broad ligament fibroids. Prophylactic ureteric stenting, a strategy debated in the past as a means of reducing intra-operative complications, is generally considered disadvantageous for preventing injuries. Current consensus suggests it should be reserved for a select group of high-risk patients.[29] Ureteric stent insertion, while necessary in many cases may be associated with increased morbidity. A review of >50,000 cases described common complications such as bladder irritability, haematuria, back/loin pain and urinary tract infections.[30] Less common, but more severe complications included stent migration, stent obstruction and ureteric perforation.

ICG and ureteric mapping provide a safe and effective way to assess ureteric location and integrity in real time during complex pelvic surgeries. Real-time visualisation enhances surgical confidence and reduces the risk of unnoticed ureteric injuries. This is achieved via cystoscopy and ureteral catheterisation (Figure 3a), delivering 4–12 hours of fluorescence. In our practice, a 25F rigid cystoscope and 6F ureteric catheters are used, with 5 mL of dilute ICG (25 mg in 10 mL sterile water) instilled 1–2 cm into the ureteric orifice. Using smaller catheters and limiting insertion depth minimises risks associated with larger stents, offering a safer approach.

A pilot RCT, the ICE trial (Indocyanine Green versus Conventional Ureteric Stenting in Endometriosis Surgery), will compare ICG-guided ureteric identification with stenting. The study will assess whether ICG can reduce operative time, post-operative pain, and stent-related morbidity.[31]

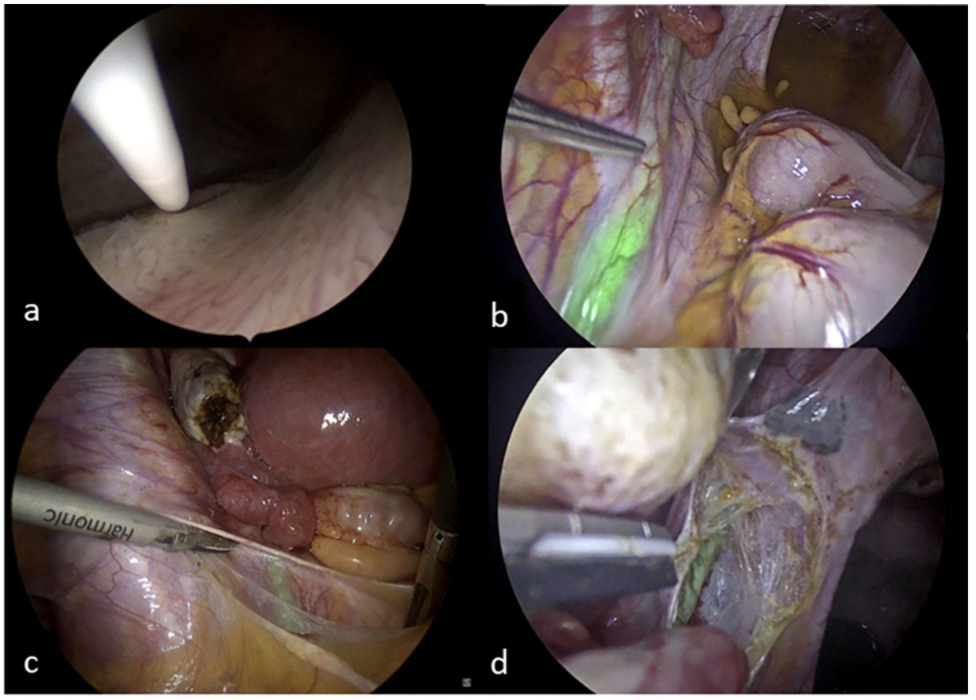

Figure 3. Stepwise fluorescent visualisation of the ureter in laparoscopic excision of endometriosis. a) Cystoscopy-guided ureteric catheterisation for ICG administration, b) identification of the ureter prior to ureterolysis, c) ureterolysis in frozen pelvis guided by ICG, d) ureterolysis and excision of endometriotic nodule on the left USL.

ICG: Indocyanine green, USL: Uterosacral ligament.

The first reported use of ICG for ureter identification was by Lee et al.[32] during robot-assisted ureteroureterostomies, demonstrating its value in real-time ureter visualisation and distinguishing healthy from diseased tissue without complications. In gynaecology, Park and Farnam.[33] used ICG with NIR imaging for ureter mapping during endometriosis surgery, enhancing localisation of lesions, surgical precision, and reducing tissue damage. Similarly, Siddighi et al.[34] reported a 100% success rate in ureter visualisation without intra- or post-operative complications. Mandovra et al.[35] validated ICG as a reliable, cost-effective, and user-friendly tool for pelvic surgeries in a cohort of 30 cases.

ICG is a valuable tool for assessing ureteric vascularity after complex dissections via intravenous administration, enabling the detection of adventitial de-vascularisation and tissue hypoperfusion for prompt diagnosis and intervention. Raimondo et al.[36] evaluated NIR-ICG imaging during endometriosis and ureterolysis procedures, reporting an average procedural time of 5.4 minutes for 31 ureters with no adverse events. NIR-ICG was particularly effective in identifying ischemic areas undetectable under standard lighting, facilitating critical intraoperative decisions such as stent placement. The method was reproducible amongst the surgical team, with excellent clinical and radiological outcomes. The authors concluded that NIR-ICG is a safe, efficient, and reliable technique for assessing ureteral vascular integrity, enhancing decision-making in complex surgical cases.

Assessing Bowel Perfusion in Segmental Bowel Resection for Deep Infiltrating Endometriosis

DIE often affects multiple pelvic and abdominal organs, necessitating complex multidisciplinary surgical management. For symptomatic patients with advanced bowel involvement, treatment options include bowel shaving, disc excision, or segmental bowel resection. However, the complexity of these procedures increases the risk of long-term morbidity, particularly in cases of bowel ischaemia and anastomotic leaks.

Studies have highlighted the clear benefits of utilising intraoperative ICG to assess bowel vascularity and integrity, particularly in colorectal disease.[37] A meta-analysis by Liu et al.[38] reviewed over 4,000 patients and demonstrated a significantly reduced anastomotic leak rate in the ICG group [3.8% vs. 7.8%, odds ratio: 0.44; 95% confidence interval (CI): 0.33–0.59; *P*<0.00001]. Furthermore, a more recent systematic review and meta-analysis by Elmajdub et al.[39] reported a 45% reduction in anastomotic leaks.

Table 1. Summary of ICG administration route and suggested dosage.

Use	Administration	Dilution	How it is given	References
Bowel vascularity Ureteric vascularity Ovarian vascularity Endometriosis identification	IV	25 mg ICG in 10 mL sterile water 2.5 mg/mL 1 mL injection = 2.5 mg	3 mL (7.5 mg) followed by a 10 mL saline flush Boluses can be repeated	31,32,35,36,38,42,47
Tubal patency Cavity check	Into uterus	25 mg ICG diluted into 50 mL sterile water	Via uterine manipulator	21,26,27
Ureteric visualisation	Into ureteric orifices	25 mg ICG in 10 mL sterile water 5 mL into each ureter	6F ureteric catheters and 25F cystoscope	28-30
Demarcation of bladder/check bladder injury	Into bladder via catheter	25 mg ICG diluted into 200 mL sterile water	Via bladder syringe	15
Vaginal mucosa	Intravaginal application e.g. swab in vagina	25 mg ICG in 10 mL sterile water	10 mL of 2.5 mg/mL	19-21
Fibroid capsule	Intra-fibroid injection	25 mg ICG in 10 mL sterile water	3 mL of 2.5 mg/mL	24

ICG: Indocyanine green, IV: Intravenous.

Although data specific to endometriosis is limited, the first documented use of ICG during bowel resection for endometriosis was reported in 2018 by Seracchioli et al.[40] They described the intravenous use of ICG to delineate a precise dissection plane between well-perfused healthy bowel and hypovascular endometriotic nodules. Before resection and anastomosis, ICG allowed for a visual assessment of the blood supply to the anastomosis, potentially reducing post-operative risks. A feasibility study by Raimondo et al.[36] evaluated the use of NIR-ICG imaging to assess bowel vascularisation and guide the transection line following full-thickness bowel resections (segmental and discoid) for endometriosis in 32 patients. No adverse reactions to ICG were reported, and the average assessment time was 3–5 minutes. The study demonstrated excellent intraoperator agreement, and the authors concluded that NIR-ICG imaging for anastomotic perfusion assessment after discoid or segmental resections for rectosigmoid endometriosis is a feasible, safe, and reproducible method.

An example of the assessment of bowel vascularity is demonstrated in Figure 4, where ICG has been administered intravenously to reveal adequate perfusion (Table 1).

ICG also appears to have a role in endometriosis bowel shave surgery for assessing bowel integrity and identifying potential ischaemic areas. Bourdel et al.[41] conducted a study involving 21 patients undergoing laparoscopic surgery for DIE and rectal shaving, aiming to use intravenous ICG to assess the vascularity of shaved areas and potentially reduce postoperative complications such as fistulas. Intravenous ICG was administered following the shave procedure, and fluorescence was visually assessed using a Likert scale.

The results showed no adverse reactions to ICG, with 81% of patients demonstrating very good fluorescence at the rectal shave site. In one case, additional sutures were placed, which improved fluorescence. No post-operative bowel complications occurred. The authors concluded that ICG fluorescence imaging is feasible in endometriosis surgery and may serve as a valuable tool to enhance patient safety in bowel surgery for endometriosis.

Assessing Ovarian Perfusion in Acute Torsion

In cases of ovarian torsion, the decision between oophorectomy, detorsion, or cystectomy largely relies on the surgeon’s visual assessment of the ovary intraoperatively. While this decision-making process has significant implications, no standardised guidance or assessment techniques currently exist to evaluate ovarian perfusion and salvageability. Nicholson et al.[42] conducted a feasibility study using ICG in 12 confirmed cases of surgical ovarian torsion. ICG fluorescence was visualised

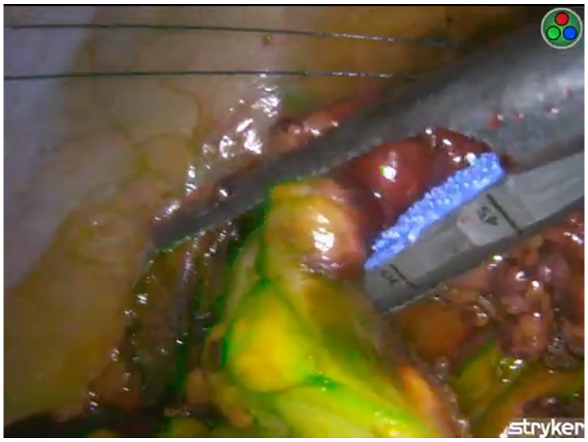

Figure 4. Assessing bowel vascularity with intravenous ICG prior to anterior resection.

ICG: Indocyanine green.

in the detorted adnexa in 10 out of 12 cases following intravenous administration, enabling partial or total ovarian conservation, even in a case where preoperative Doppler flow was absent.[42]

The evidence suggests that ICG can provide clinically valuable information during laparoscopy, reserving oophorectomy for cases of established necrosis, indicated by the absence of ICG fluorescence.[43] This approach has the potential to reduce unnecessary oophorectomies in young women, which can have devastating long-term consequences.

Identification of Endometriotic Implants

During endometriosis surgery, one of the most significant challenges remains the accurate diagnosis of endometriosis, despite advancements in surgical techniques. These challenges arise from the polymorphic and diverse appearance of endometriosis within the pelvis. This variability can lead to misdiagnosis, underestimation of disease depth, and incomplete removal of nodules. Such outcomes may contribute to disease progression and increased recurrence rates.[37]

Recurrence rates for endometriosis vary widely, ranging from 5% to 50%, depending on several factors. Therefore, any adjunct that aids in detecting endometriosis, particularly subtle disease during laparoscopy, is essential. Given the high degree of neovascularisation associated with endometriotic nodules, ICG may play a role in improving detection. However, the evidence in the current literature remains variable.

Cosentino et al.[44] conducted a single-centre prospective study evaluating 27 patients. The study aimed to assess the use of NIR-ICG during laparoscopic surgery for identifying endometriosis lesions. NIR-ICG was found to effectively detect both visible and occult endometriotic lesions, with a positive predictive value of 97.8% and a negative predictive value of 82.3%. However, not all lesions were identified, and the authors concluded that NIR-ICG should complement, rather than replace, white-light evaluation.

The Gre-Endo trial, a prospective single-arm study by Turco et al.[45], evaluated the use of NIR imaging with ICG for the detection of endometriosis lesions during surgery. After an initial exploration using white light (WL) mode, patients received an ICG injection and were subsequently examined using NIR mode. Lesions were classified based on their visualisation with WL, NIR-ICG, or a combination of both.

Of the 240 lesions identified, 207 (86.2%) were detected with WL imaging, with 200 confirmed as true positives. The remaining 33 lesions (13.8%) were only identified with NIR-ICG and were all confirmed as pathological, indicating a 100% detection rate for occult lesions using NIR-ICG.

The authors concluded that NIR-ICG imaging, both alone and in combination with WL, is highly effective for intraoperative detection and fluorescence-guided excision of endometriosis. Additionally, NIR-ICG enabled the removal of occult lesions that might otherwise have been missed, potentially reducing postoperative pain and the risk of disease persistence and relapse.

Conversely, a systematic review and meta-analysis by Zhuang et al.[46] evaluated the diagnostic efficacy of intraoperative ICG imaging compared to traditional WL imaging. The analysis included six studies and found that, although ICG imaging may assist in visualising occult endometriosis lesions, it did not demonstrate superior diagnostic accuracy over WL imaging. The sensitivity for WL was reported at 0.88 (95% CI: 0.81–0.93), compared to 0.64 (95% CI: 0.36–0.84) for ICG. Similarly, the specificity for WL was 0.85 (95% CI: 0.49–0.97), compared to 0.88 (95% CI: 0.66–0.97) for ICG.

Furthermore, Siegenthaler et al.[47] conducted a prospective study evaluating the role of NIR-ICG imaging in endometriosis detection. While ICG identified additional lesions beyond standard WL imaging, only one was histologically confirmed as endometriosis. The authors concluded that NIR-ICG has limited diagnostic value but may aid in resecting

Table 2. Summary of clinical applications of indocyanine green (ICG) in benign gynaecological surgery.

Application	Purpose	Route of administration	Key benefit	References
Bladder demarcation	Identify bladder margins and assess injury	Intravesical (via catheter)	Reduces risk of bladder injury during dissection	15
Ureteric visualisation	Intraoperative mapping of ureters	Intracystic → ureteric catheter	Enhances safety in complex pelvic surgery	35
Ureteric vascularity assessment	Assess blood supply post-dissection	Intravenous	Detects ischaemia and guides stenting decisions	36
Uterine cavity during myomectomy	Detect endometrial breach	Intrauterine (via manipulator)	Enables repair to reduce uterine rupture risk	23
Tubal patency assessment	Confirm tubal patency	Intrauterine (via manipulator)	Real-time visualisation without pelvic staining	27
Vaginal mucosa delineation	Improve vault closure or endometriotic excision	Intravaginal injection or swab	Enhances visualisation and surgical precision	21
Fibroid pseudo capsule delineation	Define resection planes during myomectomy	Intramyoma injection	Minimises bleeding and aids complete resection	24
Uterine niche identification	Mark niche for laparoscopic repair	Intrauterine	Improves accuracy, avoids need for hysteroscopy	25
Ovarian perfusion in torsion	Assess salvageability	Intravenous	Supports ovary-sparing decisions	42
Bowel perfusion (endometriosis resection)	Assess anastomotic vascularity	Intravenous	Reduces risk of post-operative leak	37
Endometriotic lesion detection	Identify occult or deep nodules	Intravenous	Improves completeness of excision	47

deep-infiltrating nodules by improving visualisation and defining tissue borders.

Although there is no definitive consensus, and further randomised controlled trials are needed, ICG appears to be a helpful adjunct in improving the diagnosis of endometriosis and increasing the identification of more subtle lesions.

Discussion

ICG has emerged as a versatile and valuable tool in minimally invasive gynaecological surgery, providing real-time imaging to enhance precision and reduce intraoperative risks. ICG's expanding use in benign gynaecology represents a promising frontier in minimal access surgery, given its fantastic safety profile comparable to conventional diagnostic dyes.[6,7] The advantages of ICG have been discussed in several contexts, including improved visualisation of anatomical structures, more accurate assessment of tissue perfusion, and the ability to make real-time decisions on interventions.[42,48]

The benefits of ICG fluoroscopy are best described in colorectal surgery, where a systematic review undertaken by a panel of experts commissioned by the European Association for Endoscopic Surgery outlined a strong body of evidence to support its use in several surgical procedures, including laparoscopic cholecystectomy and bowel resection surgery.[49]

In this context, administration of ICG to assess vascular perfusion of bowel adventitia has shown a reduction in operative complications and length of hospital admission, and a further budget impact analysis predicted an overall reduction in cost. Further described in this study is a qualitative evaluation of the clinicians' perceptions of intra-operative ICG fluoroscopy, which revealed greater confidence in anatomical identification and described ICG techniques as 'easy to use'. In this context, the use of NIR imaging has the potential to reduce the surgeon's cognitive load and shorten the learning curve for trainee surgeons by providing enhanced visualisation that supports safe procedural navigation to avoid visceral injuries. This facilitates hands-on learning in a controlled and safer environment, allowing trainees to gain experience and confidence while minimising patient risk.

ICG use in benign gynaecology remains limited by the lack of standardised guidelines and the variability in application techniques. So far, few studies have assessed the direct benefit of ICG versus WL or methylene blue assessment and impact on overall patient morbidity and mortality, particularly in benign gynaecological conditions. Presented in this study are the conventional dosing of ICG utilised in many settings, yet targeted research is needed to establish optimal protocols and dosing strategies to ensure consistent and safe results across different surgical settings. Additionally, accessibility of equipment capable of NIR fluorescence imaging is crucial for the effective implementation of ICG in clinical practice.

While standard dosing protocols for ICG are well established, the visibility and efficacy of fluorescence can vary depending on the imaging platform. Differences in fluorescence sensitivity, signal intensity, and image clarity have been reported between systems, largely due to variability in both hardware and software design.[50] Surgeons should be familiar with their specific equipment and may need to tailor ICG dosage or timing to optimise fluorescence-guided imaging in real time.

Moving forward, developing standardised guidelines and increasing surgeon familiarity with ICG in benign gynaecological surgery could lead to significant improvements in patient safety and postoperative recovery. By addressing these gaps, ICG can become an integral part of gynaecological surgery, enhancing surgical precision and improving outcomes in complex cases.

Strengths and Limitations

This review offers a comprehensive synthesis of current evidence on ICG use in benign gynaecology, aiming to address gaps in practical guidance and support wider adoption in clinical practice. We recognise that the quantitative effects of ICG need further investigation with large-scale prospective studies and randomised controlled trials. The recently launched ICE trial,[31] which directly compares ICG with conventional ureteric stenting, exemplifies the type of evidence needed to fully harness the benefits of ICG in benign gynaecology. Future study of the cost-benefit of ICG fluorescence imaging in laparoscopy is imperative to wider application in clinical practice.

Conclusion

ICG is a valuable adjunct in minimally invasive benign gynaecological surgery, enhancing visualisation, surgical precision, and intraoperative safety. Its applications span tissue perfusion assessment, prevention of urinary tract injuries, and improved detection of endometriosis and ovarian or bowel vascularity. With a strong safety profile and increasing access to NIR imaging, ICG has the potential to improve outcomes across a range of procedures. However, high-quality studies are still needed to define its role in routine practice. Ongoing research, such as the ICE trial,[31] will help clarify its comparative benefits and support evidence-based integration.

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