

# Intra-ureteric indocyanine green for ureteric visualisation in complex benign gynaecological surgery: a prospective series of 50 cases

✉ Bomee Kim, ✉ Julia Mazurek, ✉ Rakesh Thing, ✉ Thomas Kurka, ✉ Rebecca Mallick

Department of Gynaecology, Princess Royal Hospital, University Hospitals Sussex NHS Foundation Trust, Brighton, United Kingdom

## ABSTRACT

Ureteric injury is a serious complication of gynaecological surgery, particularly in cases involving deep endometriosis. This prospective cohort study assessed the feasibility and safety of intra-ureteric indocyanine green (ICG) for real-time ureteric visualisation in complex endometriosis surgery at a tertiary referral unit. Fifty consecutive patients undergoing laparoscopic procedures received cystoscopy-guided bilateral intra-ureteric ICG. Mean additional operative time was 160 seconds. Bilateral ureteric fluorescence was achieved in all cases and persisted throughout surgery. Guidewires and intra-operative stents were required in 2% and 4% of cases, respectively. No ICG-related adverse events or ureteric injuries occurred, demonstrating a rapid, safe and reproducible technique.

**Keywords:** Cystoscopy, endometriosis, gynaecological surgery, indocyanine green, laparoscopic, ureter

## Introduction

Ureteric injury is a serious complication of benign gynaecological surgery, with an incidence of 0.5%–2%<sup>1</sup> in laparoscopic procedures, of which 70% of injuries are detected post-operatively.<sup>2</sup> In a large UK series of 14,692 laparoscopic hysterectomies, overall ureteric injury rate was reported at 0.6%, increasing to 2.2% among patients with endometriosis.<sup>1</sup> In selected high-risk subgroups such as patients with deep infiltrating endometriosis (DIE) and hydronephrosis, rates as high as 21% have been described. These figures highlight the difficulty of ureteric identification in complex pelvic surgery where anatomy is distorted, and the importance of adjunctive visualisation techniques. Conventional preventive strategies include meticulous ureterolysis and prophylactic ureteric stenting, though evidence for routine stenting is weak.<sup>3</sup>

Indocyanine green (ICG) has been safely used across multiple surgical specialties for several decades with excellent safety and predictable pharmacokinetics.<sup>4</sup> Within gynaecology, ICG with near-infrared (NIR) imaging has applications in both oncological and non-oncological surgery –from sentinel lymph-node mapping to assessment of tissue perfusion, tubal patency, bladder and ureteric identification, and evaluation of ovarian and bowel vascularity.<sup>5</sup> Reported adverse effects from ICG are rare (0.05%–0.07%),<sup>6</sup> and when administered into the ureter, remains intraluminal with negligible systemic absorption and minimal renal or ureteric toxicity. Furthermore, the dose used in this study (25 mg in 10 mL) is well below thresholds associated with systemic exposure.<sup>6</sup> Intra-ureteric administration avoids the intravascular route altogether, further reducing the potential

**Corresponding Author:** Bomee Kim, MD, Department of Gynaecology, Princess Royal Hospital, University Hospitals Sussex NHS Foundation Trust, Brighton, United Kingdom

**E-mail:** bomee.kim@nhs.net **ORCID ID:** orcid.org/0009-0009-7052-8007

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for allergic or haemodynamic effects, while providing prolonged and stable visualisation throughout surgery. In theory, improved visualisation of the ureter through the retroperitoneum using ICG should mitigate the risk of inadvertent ureteric injury and potentially lessen the need for routine pelvic sidewall opening and ureterolysis. This may subsequently reduce fibrosis, chronic pelvic pain and the complexity of repeat surgery when required.

ICG's use for ureteric delineation was first described in 2013 by Lee et al.,<sup>7</sup> who demonstrated real-time intra-operative visualisation during robotic ureteroureterostomy. Subsequently, small series have reported successful, safe and sustained ureteric mapping with ICG fluorescence,<sup>8-11</sup> highlighting its potential to enhance safety. Building on these developments, we report a single-surgeon prospective series of 50 complex benign gynaecological procedures in which intra-ureteric ICG with NIR-imaging was employed for real-time ureteric identification. The objectives were to assess the feasibility and safety of this technique in routine tertiary practice and explore its potential to reduce reliance on prophylactic ureteric stenting while enhancing safety in minimally invasive gynaecological surgery.

## Methods

### Study Design

A prospective analysis of 50 consecutive patients undergoing complex benign gynaecological surgery between February 2024 and June 2025 was performed. Data on intra-operative #Enzian classification, success of NIR-fluorescence and operative outcomes were collected at a single-surgeon unit within a tertiary referral centre specialising in endometriosis and complex non-oncological gynaecological surgery. All patients with DIE were followed up post-operatively as routine practice at six months.

### Inclusion and Exclusion Criteria

Eligible patients were adults ( $\geq 18$  years) undergoing complex benign gynaecological surgery in which difficult ureteric visualisation was anticipated - such as procedures for DIE, dense adhesions, large fibroids or significant adenomyosis -and where ureteric stenting, ureterolysis or enhanced identification would typically be considered. All patients provided written consent for cystoscopy and intra-ureteric ICG. Patients with known allergy to ICG or iodide, significant renal impairment or ureteric obstruction precluding catheterisation, active

urinary tract infection, pregnancy, or prior urological ureteric reconstruction were excluded. Cases were also excluded if intra-operative judgement deemed ureteric catheterisation unsafe or unnecessary (i.e., in the case of a simple hysterectomy). As ureteric ICG was introduced as a standard component of complex gynaecological surgery at this centre, there was no requirement for a full ethical approval according to local institutional policy and the United Kingdom Health Research Authority guidance.

### Surgical Methods

Cystoscopy with ICG was performed prior to commencement of all surgical procedures. A 22 or 25 French (Fr) 30-degree rigid cystoscope was used to place a 6 Fr open-tip ureteric catheter 1-2 cm into each ureteric orifice. ICG was prepared as 25 mg of dye diluted in 10 ml of sterile water, with 5 mL instilled into each ureter. The time taken to perform cystoscopy and ICG injection was recorded. Use of guidewires, adequacy of ureteric visualisation under fluorescence, and any intraoperative or postoperative complications were also documented.

## Results

Fifty patients were included. Indications predominantly included deep endometriosis, laparoscopic hysterectomy with or without endometriosis surgery, and other complex benign procedures (Table 1). All cases of DIE were classified according to #Enzian classification. Deep endometriosis was predominantly multicompartamental, with compartment B (uterosacral ligaments and pelvic sidewall) involved in 92.6% of cases, most commonly as moderate to severe disease (B2-B3). Compartment A (rectovaginal septum/retrocervical region) and tubo-ovarian adhesions (T category) were each present in 85.2% of patients, again largely reflecting A2-A3 and T2-T3 disease. Rectosigmoid involvement (compartment C) was identified in 74.1% of cases, with a substantial proportion demonstrating lesions  $\geq 1$  cm (C2-C3). Peritoneal disease was present in 77.8% of patients, while ovarian involvement was noted in 63.0%. Extra-genital disease (F category) occurred in over half of cases (55.6%),

**Table 1.** Indications and index procedures.

Indication/procedure	n (%)
Deep endometriosis surgery	30 (60)
Laparoscopic hysterectomy	10 (20)
Hysterectomy with endometriosis surgery	7 (14)
Other complex benign procedures	3 (6)

most frequently adenomyosis and ureteric involvement, with bladder and non-rectal bowel disease observed less commonly.

The mean additional time required for cystoscopy and ICG administration was 160 seconds (standard deviation: 23.6; range: 120-210 s). A guidewire was required in 1/50 (2%). Bilateral ureteric fluorescence was achieved in 50/50 (100%) and this persisted throughout each procedure. Intra-operative stenting was performed in 2/50 (4%). No intra-operative or post-operative complications occurred, and no iatrogenic ureteric injuries were observed. All patient with DIE were followed up six months post-operatively with no reported ICG or procedure-related complications. Examples of the ureteric fluorescence achieved from intra-ureteric ICG are shown in Figure 1.

## Discussion

### Main Findings

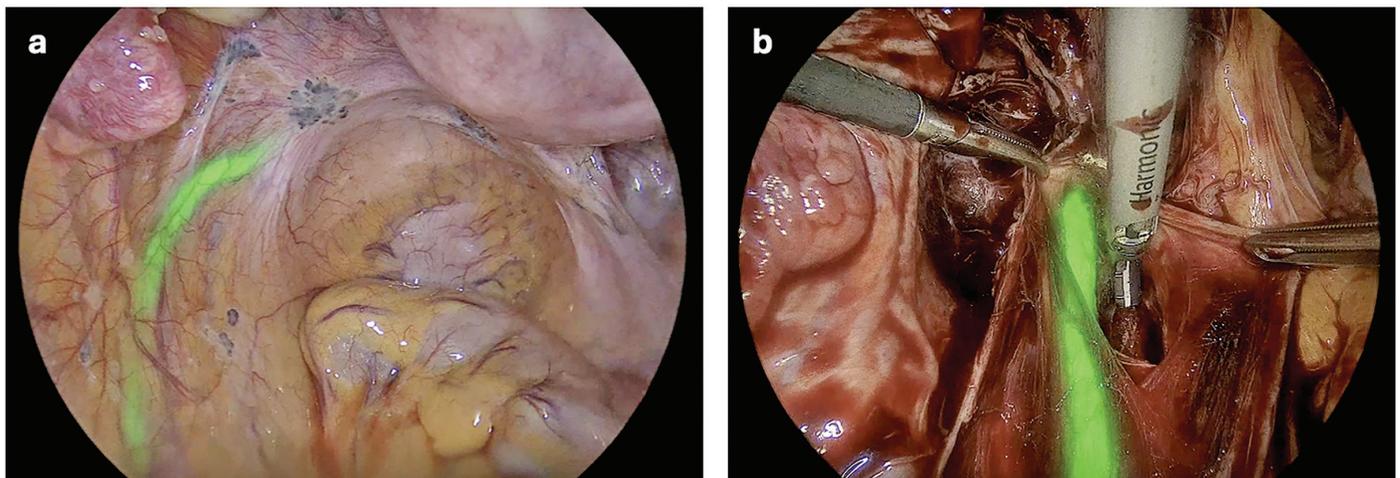
In this prospective series of 50 consecutive high-risk benign gynaecological cases, intra-ureteric ICG achieved 100% bilateral ureteric fluorescence, required an average of 160 seconds to set up, and was not associated with any complications or ureteric injuries up to 6 months post-operatively. Ureteric catheters were placed 1–2 cm into the ureter to minimise instrumentation, reduce the risk of ureteric trauma, and allow controlled instillation under direct cystoscopic vision. Deeper catheter placement may be considered in selected cases, especially if ICG back flow spillage into the bladder occurs, however was not routinely required. Intra-operative ureteric stenting was required in two cases with pre-existing hydronephrosis in whom extensive dissection was necessary to mobilise the

ureters: a multidisciplinary decision in conjunction with urology colleagues. Guidewire use was reserved for when there was difficulty angulating the ureteric catheters directly into the ureteric orifices, encountered in only one case in this cohort. These findings demonstrate the feasibility and safety profile of intra-ureteric ICG and suggest that it enables dynamic, continuous real-time visualisation of the ureteric course.

### Strengths and Limitations

Strengths of this series include prospective data capture, uniform surgical technique, and a deliberately high-risk population managed in a tertiary referral centre, highlighting the feasibility to integrate intra-ureteric ICG as a surgical adjunct in benign gynaecology. A limitation of this study is potential selection bias, as all procedures were performed by a single surgeon in a high-volume tertiary endometriosis centre with expertise exceeding that of many general gynaecology settings. Consequently, while cystoscopy and intra-ureteric ICG instillation were rapid, procedural setup and dye preparation may add incremental time depending on local logistics. The findings may therefore be less generalisable to lower-volume units or centres without NIR imaging, and the technique has an associated learning curve requiring familiarity with fluorescence optimisation and workflow integration. Nevertheless, intra-ureteric ICG is a straightforward, transferable technique that can be adopted in most gynaecological settings using existing equipment, with structured training supporting uptake in lower-volume centres.

Intra-ureteric ICG involves additional costs for dye, cystoscopy, and ureteric catheters, but these may



**Figure 1.** Laparoscopic view of intra-ureteric indocyanine green and near-infrared fluorescence during a) laparoscopic excision of endometriosis involving the ureter b) ureterolysis in a frozen pelvis secondary to endometriosis.

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compare favourably with prophylactic ureteric stenting when stent-related morbidity and postoperative resource use are considered. Formal cost-effectiveness analyses are warranted.

Upcoming multicentre randomised trials –such as the ongoing ICE trial comparing ICG with conventional stenting– will be key to defining indications, optimising dosing protocols, quantifying cost-effectiveness, and evaluating broader applicability and reproducibility in routine practice.<sup>12</sup>

### **Strengths and Limitations in Relation to Other Studies**

ICG fluorescence imaging is now well established across multiple surgical specialties –including colorectal, urological and gynaecological oncology– for real-time assessment of tissue perfusion and anatomical mapping. These established applications provide a strong foundation for its wider use in benign gynaecology.

The ureter is particularly vulnerable to iatrogenic injury during pelvic surgery, especially with dense adhesions and DIE, where fibrosis and scarring distort the ureteric course. Conventional preventive strategies, such as prophylactic ureteric stenting, may aid identification but offer limited protection. A systematic review of 10 studies involving 8,661 patients found no significant reduction in ureteric injury with prophylactic stenting (relative risk: 0.9; 95% confidence interval: 0.49–1.65).<sup>3</sup> Moreover, stenting is associated with additional morbidity, including urinary tract infection ( $\approx$ 1.5%), acute renal impairment ( $\approx$ 0.6%), ureterovaginal fistula ( $\approx$ 0.3%), haematuria, bladder irritability, and, more rarely, stent migration, obstruction, or perforation.<sup>13–15</sup> Placement also requires urological input, fluoroscopy, and radiography, increasing both cost and radiation exposure. These drawbacks underscore the need for safer and reliable methods of intra-operative ureteric visualisation. NIR imaging of instilled ureteric ICG offers such alternative –providing real-time, dynamic, and radiation-free delineation.

Our prospective series of 50 complex benign gynaecological cases adds to this growing evidence base. Bilateral fluorescence was achieved and maintained in every case, with a short setup time and no adverse events or ureteric injuries, confirming the safety, simplicity and reproducibility of the technique.

### **Future Directions**

Although the results of this study are encouraging, further research is required to quantify the true impact

of intra-ureteric ICG on ureteric injury rates, operative efficiency and overall cost-effectiveness compared with conventional techniques such as prophylactic stenting. Multicentre randomised trials will be key to defining optimal dosing, timing of administration and clinical indications. Future work should also evaluate surgeon learning curves, integration into training curricula, and wider implementation across differing institutional settings to assess generalisability and sustainability of this technique within everyday benign gynaecological practice.

### **Conclusion**

This prospective series supports emerging evidence that intra-ureteric ICG with NIR fluorescence may be safely and feasibly integrated as an adjunct in complex benign gynaecological surgery. By enabling continuous dynamic mapping of the ureteric course, this technique may reduce reliance on prophylactic ureteric stenting, limit the extent of pelvic side-wall dissection, and support safer surgery in anatomically challenging cases. Intra-ureteric ICG should be regarded as a complement to, rather than a replacement for, surgical expertise and anatomical knowledge, offering a practical, reproducible, and safe method to potentially enhance ureteric safety in minimally invasive gynaecological surgery. Further controlled studies are warranted to confirm its clinical and cost-effectiveness in order to incorporate the technique into clinical guidance and policies.

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**Informed consent:** Written informed consent for intraoperative ICG used and anonymised data collection was obtained from all patients.

**Data sharing:** All the papers cited within the article are available online via their respective publishers.

**Transparency:** The authors affirm that the manuscript is an honest, accurate, and transparent account of the studies assessed. There are no important aspects of the studies omitted.

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