

An In-Depth Analysis of Fluorescent Applications in Gynaecology

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ABSTRACT

Since Indocyanine Green (ICG) initially appeared as a fluorophore in near-infrared imaging, fluorescence vision has evolved into a crucial tool in many surgical specialties. Several innovative applications have been put forth and established themselves in clinical practice in the field of gynaecology. Investigations into various gynaecological applications—including surgical ones and those involving available dyes—were conducted. This article details specific fluorescence-guided surgery procedures that were used in the field of gynaecology, including sentinel node biopsy, mesometrium visualization, angiography of various organs, safety concerns for expectant mothers, visualization of the ureters, detection of peritoneal metastases, fluorescent contamination hysterectomy, lymphography for preventing lower limb lymphedema, tumor margin detection, and endometriosis. With the advancement of technology, additional creative research on the novel uses of fluorescence imaging in cancer surgery may contribute to establishing these methods as benchmarks for high-quality gynaecological surgery. Further research is still required to determine whether these cutting-edge techniques may also effectively improve patient outcomes and quality of life in various gynecologic cancers.

Keywords: Indocyanine green, surgery, fluorophore, fluorescence

INTRODUCTION

A new era of image-guided surgery began in 2005 with the introduction of fluorescence-guided surgery (FGS) for breast cancer sentinel node biopsy utilizing Indocyanine Green (ICG). Much better intraoperative orientation is made possible by some emerging systems that can combine these fluorescent images with white light images. Only five FGS contrast agents—fluorescein, ICG, methylene blue, and 5-alanine—are now permitted for clinical use by the American Food and Drug Administration (FDA) and the European Medicines Agency (EMA) [1]. Clinical trials are still being conducted to investigate novel fluorophores. Before their widespread clinical usage can be accomplished, we must wait for more convincing proof.

DISCUSSION

Furukawa et al. published the first study using ICG for the Sentinel Node Biopsy (SNB) method in endometrial cancer, in which 83% of patients had fluorescent nodes discovered bilaterally in all cases. False-negative nodes were not discovered.

Rossi et al. described the first SNB for endometrial cancer that was minimally invasive and found sentinel nodes in 85% of cases (17 patients). There were no false-negative cases, and positive nodes were detected bilaterally in 60% of cases. In a study comparing ICG and isosulfan blue (IB), the nodes were discovered with the naked eye in 77% of cases using IB compared to 97% of cases utilizing ICG's fluorescent characteristics.

Since up to 20% of patients with early cervical cancer present with lymph node metastases, it is of utmost importance to apply this treatment in this setting. The 5-year survival rate for patients with lymph node metastases falls from 92% to 64% with accurate nodal disease identification. Sentinel node biopsy may reduce the long-term morbidity rate associated with lymphadenectomy, which affects up to 20% of patients who have the more invasive operation.

In 10 patients, Crane et al. published the first description of an ICG usage in vulvar cancer SNB and shown that this

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Received: 24 July, 2023, **Manuscript No.** gocr-23-23274; **Editor assigned:** 26 July, 2023, **PreQC No.** gocr-23-23274 (PQ); **Reviewed:** 10 August, 2023, **QC No.** gocr-23-23274 (Q); **Revised:** 21 August, 2023, **Manuscript No.** gocr-23-23274 (R); **Accepted Date:** 29 August, 2023; **Published:** 31 August 2023

Citation: Beth E, (2023) An In-Depth Analysis of Fluorescent Applications in Gynaecology, *Gynecol. Obstet.* 13:5

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technique was workable, but only in patients with a BMI under 25 kg/m². It was connected to the groin's substantial adipose tissue and hindered fluorescence penetration. This problem was also brought up in a study where the researchers discovered that in the group of patients with a BMI more than 30 kg/m², sentinel nodes were discovered in 93.3% of cases when radio-colloid was utilized, and in 86.7% of cases in the ICG group. The identification rate of sentinel nodes was 100% if ICG was combined with radio-colloid in 12 patients with early-stage vulvar cancer.

The detection rate for seven patients with ovarian cancer using ICG and radio-colloid was 100%. Sentinel nodes were identified in all five patients in a series utilizing only ICG. According to recently released preliminary data from the prospective multicenter SELLY trial, the detection rate of sentinel nodes with ICG was 67.7%, with patients who underwent rapid staging having a substantially higher detection rate. ICG was used to diagnose all four individuals who had lymph node metastases when they first appeared. These findings were less than those that had previously been made public in the review study, when it was discovered that the detection rate was 88%. To demonstrate the true potential of fluorescent tracers in SNB treatments for ovarian cancer, more study is necessary.

It is still up for debate as to whether the cervical injection should be used for endometrial cancer or the uterine injection. Using two fluorophores concurrently may allow the detection of sentinel nodes. No matter where the injection was given, Methylene blue and ICG could be seen in two patients who shared similar lymphatic systems. One instance involved staining the lymph nodes with both fluorophores. The real positive para-aortic sentinel node, however, was only stained with ICG after uterine fundus injection in the second instance and not with MB after cervical injection. It was suggested to use radio-colloid and fluorescein and ICG-mixed multispectral fluorescence imaging during prostatectomy [2]. Unquestionably, in the near future, multispectral image-guided surgery will be the ideal tool for differentiating anatomical structures from various fluorophores.

One of the main goals of any surgical research is to improve surgical methods in order to improve oncologic outcomes. RJ Heald's concept of Total Mesorectal Excision (TME) altered both the idea of embryological planes and the surgical approach to a number of malignancies [3]. This resulted in better local control following surgery for rectal cancer. Several organ-specific surgical procedures also used this concept. Höckel et al. also suggested using compartmental surgery with an embryological foundation to treat gynecologic cancer [4]. The injection of ICG into the uterine corpus was used in the publication by Kimmig et al. to assist the imaging of compartments. Complex lymphatic veins and lymph nodes can both be seen. Hence, fluorescence allows for the visualization of the entire organ compartment. An intraoperative lymphography identified two lymphatic flow pathways: the first followed uterine veins to the pelvic iliac lymph nodes, while the second followed ovarian vessels to the para-aortic lymph nodes.

The intraoperative imaging of tissue vascularization makes it possible to use ICG for the detection of endometriosis. 100 lesions were observed in white light in a group of 27 patients participating in a Gre-Endo trial pilot study, and an additional 16 lesions were discovered using fluorescence guiding. 173 lesions were removed from 63 patients, and 90.4% of them were determined to be histologically verified endometriosis. With the naked eye, 166 (96%) lesions were discovered; with ICG, 32 (18.5%) lesions were discovered.

In the case of segmental resection of deeply infiltrating endometriosis of the recto sigmoid region of the colon, the use of ICG was proven to be helpful. A link between the vascular patterns of recto sigmoid endometriosis and the hypovascular pattern (60%) in bigger bowel endometriosis was discovered in a study by Raimondo et al [5]. Recent research on the use of Artificial Intelligence (AI) in intraoperative tissue classification with ICG perfusion of colorectal cancer suggests that this concept may also be applied to the evaluation of endometriosis.

It must be emphasized that endometriosis FGS may be affected by prior retroperitoneal surgery, fibrosis, reduced neo-angiogenesis caused by estrogen-progestin use, or gonadotropin-releasing hormone agonist, which may change microcirculation and ultimately affect endometriosis identification [6].

A tomography-guided percutaneous injection of ICG was carried out in three patients who had metastatic-suspected lesions resulting from cervical malignancies or carcinosarcoma that were discovered on a PET/CT scan. The lesions were then discovered via laparoscopic fluorescence visibility. This method could be applied to small, hard-to-reach tumors that are suspected of being cancerous.

CONCLUSION

In gynaecology, fluorescence-guided surgery has also established a solid presence. This image-guided procedure provides the surgeon with immediate control over the operating view, which is obviously advantageous. We provided a thorough analysis of the applications that are currently in use in gynaecology, demonstrating that this area also makes use of contemporary technology for a number of widely used tactics. Unquestionably, in order to deploy this technology more widely, we will need large-scale, well planned studies that will provide the requisite proof of potential uses.

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