

ICG NIR Fluorescence

Subjects: Others

Contributor: Dragos Serban

Nowadays, surgical innovations incorporate new technological conquests and must be validated by evidence-based medicine. The use of augmented reality-assisted indocyanine green (ICG) fluorescence has generated a myriad of intraoperative applications such as demonstration of key anatomical landmarks, sentinel lymph nodes, and real-time assessment of local blood flow.

Keywords: ICG NIR Fluorescence ; augmented reality-assisted indocyanine green ; colorectal surgery

1. Introduction

The use of indocyanine green (ICG) in surgery was envisaged three decades before laparoscopy, but despite being innovative and potentially path-breaking, it did not thrive due to insufficient technological development and lack of researchers in the field ^[1]. Almost 70 years after Dr. Fox had asked one of his patients for a safe intravenous dye that could be used for functional studies on the heart, today, surgeons are using ICG with increased interest in augmented reality surgery. The molecule of ICG has a unique quantum profile, being able to emit endogenous fluorescence when a beam of near-infrared light is cast upon it. This method allows for the accurate identification of anatomical structures and real-time assessment of local blood flow. It has been used for decades in ophthalmology for imaging retinal and choroid blood flow, due to its ability to provide deeper information about choriocapillaris, beneath the pigmented retinal layers ^{[2][3]}. Today there is an exponential growth of papers pertaining to surgical uses of ICG and a myriad of intra-operative and clinical applications demonstrating not only a genuine interest but possibly the much sought-after wide peer acceptance. Enhancement of conventional human senses through augmented reality that can accurately locate anatomical structures and provide real-time functional information on tissues on the basis of ICG's fluorescent properties is not only seductive but has the potential to be a game-changer in the surgical field. Like all newly developed technologies, near-infrared fluorescence (NIR)-assisted surgery must satisfy unmet clinical needs, be safe and cost-effective, and provide advantages over traditional approaches.

Whether the employment of ICG in surgical procedures is always pertinent, or whether it is contributory to the operative or clinical decision, is yet to be determined. Still, the method has strong scientific support, and evidence-based data suggest its usefulness in specific situations such as identification of anatomical landmarks and real-time assessment of local blood supply. Despite its many theoretical applications, the technique has limitations generated by auto-quenching, diffusion, dimerization, rapid half-life in the bloodstream, and low quantum yields ^{[4][5][6]}. The safety profile of the dye is excellent, and its use became very appealing to an increasing number of surgeons who are using it off-label for various surgical applications. Because some of the studies related to the use of ICG in colorectal surgery are pushing to demonstrate the obvious or the unnecessary, we asked ourselves whether ICG is used redundantly in particular circumstances.

2. Applications of ICG NIR Fluorescence

2.1. ICG NIR-Enhanced Surgery in Preventing Anastomotic Leaks (AL)

Although ICG NIR fluorescence might not be recommended as a routine examination in colonic surgery, it has been proved to be useful in the vascular assessment of anastomoses in left colic and rectal cancer surgery. The lower the anastomosis level, the more important the assessment of the blood supply in preventing future AL. Further randomized studies are expected to determine the adequate doses and quantitative parameters to define a satisfactory blood supply.

Creating more elaborated surgical techniques usually prolongs surgery, but the intraoperative fluorescent angiography with ICG takes only 4 to 5 min and is very safe. With the development of novel technologies, NIR fluorescence is practically an option included in most of the laparoscopic and robotic image acquisition systems, with the possibility of overlapping infrared and visible spectrum images in real-time. The ICG fluorescence-based enhanced reality has passed the experimental stage and became useful in everyday surgical practice. At the expense of a few additional minutes on

the operative times, all authors reported that the final outcome was in all cases a decreased incidence of the AL. One should bear in mind that the definitions of this complication varied widely from suggestive clinical criteria to CT documentation of perianastomotic collections or peritonitis. However, more randomized clinical studies on a higher number of patients are needed to confirm the most adequate dose and to develop high-contrast, quantitative algorithms for blood supply evaluation.

2.2. ICG NIR-Assisted Surgery Performance in Detecting Sentinel Lymph Node (SLN)

ICG NIR fluorescence proved to be a reliable tool in evaluating the lymphatic flow and in identifying the SL. However, with a universally accepted lower clinical significance for the concept of SL in colorectal surgery in comparison to breast and skin malignancies, the use of this method in establishing suitable candidates for limited colonic resections remains controversial [7][8][9][10][11].

2.3. The Usefulness of ICG in Sentinel Lymph Node (SLN) and Lymphatic Basin Identification

Compared to traditional dyes, ICG offers undeniable advantages in assessing the lymphatic flow; it allows for greater accuracy than Lymphazurin, and methylene blue in detection of deeper lymphatic structures. This aspect is particularly important in obese patients, making the dissection easier and less extensive. When compared to radioactive dyes such as ^{99m}Tc, ICG is cheaper and avoids the risks related to radiation exposure [12][13].

3. Conclusions

Near-infrared (NIR)-enhanced surgery has the potential to change paradigms, but up until now, there have been no guidelines or standardized uses for this method. Promising studies and favorable systematic reviews do not suffice when it comes to embracing a new surgical technique. Although the safety profile of the ICG is unquestionable, the sometimes-excessive use of the method would only increase costs and the complexity of an operation. Lack of homogenous studies, low statistical power, and confounding evidence is common amongst publications supporting the use of ICG in colorectal surgery. Viewed by some authors with skepticism, by others with enthusiasm, NIR augmented reality seems to be shaping its place in colorectal surgery. Adding NIR to the image acquisition software in laparoscopic and robotic surgery facilitates the use of this augmented reality when the surgeon needs more real-time information about the blood or lymphatic flow or the precise location of anatomical landmarks in order to avoid iatrogenic damage. Although superfluous if performed by routine in colorectal surgery, ICG NIR may be a game-changer in particular situations, as proven in low colorectal anastomosis or lateral pelvic lymph node dissection.

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