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APPLICATION OF INDOCYANINE GREEN-ENHANCED FLUORESCENCE IN COLORECTAL ROBOTIC SURGERY: A NEW TECHNOLOGY TO PREVENT ANASTOMOTIC LEAKAGE

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SUMMARY

ABSTRACT

Despite recent advances in surgical techniques, the most common complication in colorectal surgery remains anastomotic leakage (AL).

Pathogenesis of AL is still unclear. Several studies have found correlation between poor local tissue oxygenation secondary to inadequate perfusion and AL.

For a surgeon is not simple to quantify intraoperatively perfusion of bowel before and during anastomosis.

Indocyanine Green (ICG) appears to be a new technology on preventing AL in colorectal surgery. Actually, this technology has been proposed to assess anatomy, perfusion of tissue and lymphatic drainage. In colorectal surgery, ICG fluorescence imaging can aid surgeon in detecting anastomotic perfusion and avoid risk of AL.

Recent introduction of robotic surgery presents additional advantages over laparoscopic surgery: 3D camera controlled by surgeon, seven degrees of freedom of instruments, tremor-filtering mechanism.

In this study we investigated the use of indocyanine green-enhanced fluorescence in robotic colorectal surgery to prevent risk of AL.

INTRODUCTION

Despite recent advances in surgical techniques, the most common complication in colorectal surgery remains anastomotic leakage (AL); its reported rate varies from 1 to 20%, and this percentage increases in anastomosis performed in distal colon and rectum[1].

The rate of patients with an anastomotic leak that requires surgical revision is from 10 to 35% with a mortality rate of 6 to 22%[2].

Pathogenesis of AL is still unclear. Several studies have found correlation between poor local tissue oxygenation secondary to inadequate perfusion and AL.

For a surgeon is not simple to quantify intraoperatively perfusion of anastomosis: during surgery, it's possible to evaluate tissue color, peristalsis, temperature and bleeding on the edges of the resection margins, but these findings often miss.

Indocyanine Green (ICG) appears to be a new technology on preventing AL in colorectal surgery. Actually, this technology has been proposed to assess anatomy, perfusion of tissue and lymphatic drainage. In colorectal surgery, ICG fluorescence imaging can aid surgeon in detecting anastomotic perfusion and avoid risk of AL.

The role of laparoscopic technique in colorectal surgery are well know. Recent introduction of robotic surgery presents additional advantages over laparoscopic surgery: better visualisation by 3D camera controlled by surgeon, seven degrees of freedom of instruments, tremor-filtering mechanism, precide dissection and tissue manipulation.

In this study project we investigated the use of indocyanine green-enhanced fluorescence in robotic colorectal surgery.

Primary endpoint of this study is the possibility to evaluate tissue perfusion in reducing rate of anastomotic dehiscence. Secondary, young surgeons and residents have the possibility to experiment advanced surgery and perform their learning curve.

MATERIALS AND METHODS

In this project, we proposed the use of indocyanine green-enhanced fluorescence in robotic colorectal surgery. Fluorescence imaging is integrated in the Da Vinci Xi Robotic System.

Study was conducted on General Surgery and Urgency Surgery Department, Ospedali Riuniti Torrette, Ancona.

From January 2021 to June 2023 we enrolled 25 patients consecutively (Patient's characteristics are reported on Table 1), 14 men and 11 women (mean age 67.2 years).

Mean BMI was 26, 15/25 patients have ASA score II, 10/25 patients ASA score III. 2/25 patients were smokers. 12/25 patients suffered for IPA, 5/25 for diabetes.

20/25 patients suffered from cancer, divided in:

7/25 pz rectal cancer

8/25 pz left colon cancer

5/25 pz right colon cancer

5/25 pz for diverticular disease with previous two episodes of acute diverticulitis treated conservativelly.

We performed in all patients standard robotic procedure (Da Vinci Xi system with ICG fluorescence imaging integrated) divided in:

- robotic rectum anterior resection in 7 patients
- robotic left hemicolectomy in 13 patients
- robotic right hemicolectomy in 5 patients

In all patients we performed pre-operative complete blood tests, colonoscopy and CT-scan of the abdomen in diverticulitis and total body CT scan in patients suffering for cancer.

Exlusion criteria were a history of majior gastrointestinal surgery, a history af adverse reaction to ICG and/or iodine, age>80 years and advanced cancer.

All patient received informations about procedure and we obtained informed consent.

Definition of AL included fecal material on the drain, formation of an abscess or peritonitis.

Stapled anastomosis was intra-corporeal in all the cases.

Surgical drain was positioned at the end of intervention in all cases.

All procedures were performed by single surgeon (M.G.).

Application of two associated procedure consists in the use of vital dye with a bolus of 2-5 ml of ICG solution (2.5 mg/mL) injected by the anesthesiologists, during surgery, in a peripheral vein that gives human blood fluorescence if excited with specific light in the Near Infra-Red spectrum.

During intervention, after bowel resection, we verified correct perfusion of bowel stumps by injection of ICG.

After 30-60 seconds bowel perfusion is visually confirmed with Near-Infra-Red fluorescence Da Vinci Xi imaging system.

After completion of the anastomosis, another bolus of ICG was injected for a second evaluation of correct perfusion.

So, we assessed bowel perfusion after intestinal resection, before perfoming anastomosis and after completion of anastomosis.

RESULTS

Results are illustrated on Table 2.

None of 25 patients had clinical AL.

None of 25 patients had adverse reaction to ICG.

In 5/25 patients perfusion was judged not adequate, so we extended resection (re-do resection).

Subsequently, we performed a new anastomosis and controlled it.

After completion of anastomosis, a second evaluation of perfusion was made in all cases with injection of a second bolus of ICG.

DISCUSSION

Anastomotic leakage is defined as a dehiscence of bowel wall at the site of anastomosis, that could require surgical revision and, despite development of surgical technique, remains the most common complications in colorectal surgery. The incidence of AL in ileo-colic, colo-colic, and colorectal or coloanal anastomosis is 1-4%, 2-3%, and 5-19%, respectively[3-4].

Anastomotic leakage increases mortality and morbidity, increasing necessity of hospitalization, use of antibiotics, radiological drainage, reintervention and stoma divertion. Consequently, related costs for patients and hospitals are high, due to lenght of stay and complexity of care.

Risk factors for AL are performance status of patient at intervention, surgical technique, anastomotic procedure, state of bowel perfusion.

Risk factors related to patient are: male sex, state of nutrition, diabetes mellitus, cardiovascular disease, obesity[5-6].

Interestingly, data from Literature showed no difference in AL rate between open surgery and minimally invasive techniques; anastomosis performed with stapling devices is associated with a higher incidence of AL with respect to non-stapled anastomosis. Complications following surgery can be related to technical errors such as insufficient blood supply and increased tension of anastomosis, technical failure of stapler and inadequate suturing[7]. Other risk factors related to surgical technique are the duration of the surgical procedure and the number of firings of the linear stapler.

The position of anastomosis is another risk factor for AL: the more distal the anastomosis, the higher the rate of failure, with resection of distal cancer having almost a fivefold increased risk of anastomotic leak compared with resection for colon cancer[8]. The prevalence in male sex may be related to male pelvis dimensions that increased difficulty to perform distal anastomosis.

Key point of colorectal surgery remains the assessment of adequate vascularization of bowel after resection and before anastomosis.

The adequacy of bowel perfusion is related, in colorectal cancer, to location, size and stage of tumor, pre-operative bowel obstruction, radiation therapy and perioperative transfusion[9]. Anatomic anomaly in Riolan arterial arcade and sacrifice of left colic artery during resection can relate to inadequate perfusion[10].

However, clinical judgment based on arterial pulsations, temperature and bleeding edges is not accurate, resulting in excess or insufficient colonic resection. These subjective clinical signs can understimate the risk of AL[11], due to variability between surgeon's judgment.

Objective methods as like pulse oxymetry, Doppler ultrasound, ultraviolet fluorescence, bowel wall contractility and rapid sampling microdyalisis have poor reproducibility and practicality[12].

ICG angiography can be used in guiding intraoperative management to prevent colorectal anastomotic complications[13]. Several studies demonstrated the benefits od ICG in laparoscopic surgery, reporting anastomotic complication rate of 1.4%[14].

ICG is a tricarbocyanine compound with a molecular mass of 776 Da, soluble in water. After its intravenous injection, ICG is quickly fixed to plasmatic protein and carried to the liver, where ICG is extracted unchanged. ICG is captured by a system that activates its fluorescence with the light emitted by a led. Once excited, ICG sends fluorescent signals that have the ability to cross about 10 mm of the human soft tissue. From the intravenous injection, the spread of ICG to peripheral vessels is very rapid. The reduction of the blood flow in a tissue leads to a decrease in ICG fuorescence emission[7].

Recent introduction of robotic system in surgical procedure has introducted new prespectives in colorectal surgery.

Robotic surgery has some advantages respect to open surgery and laparoscopic surgery, including better visualisation (stable three-dimensional view, magnification), precise dissection and tissue manipulation, as well as improved ergonomics, potentially reducing fatigue of the operating surgeon[15].

Firefly technology integrated with the Da Vinci Xi system enalbles intraoperative ICG fluorescence and can be use routinely for the assessment of bowel perfusion[16].

Routine utilization of ICG in colorectal surgery proved to be safe, with low rate of side effects and cost-effective measure considering reduction in AL[17]. In our study, we observed no side effects.

None of our patients suffered for AL.

Interestingly, in rectal cancer robotic surgery, the rate of AL is lower (2.2%) in patients undergoing resections with the aid of ICG compared to those undergo standard surgical procedure[18].

No statistical significative difference in incidence of AL are described between laparoscopic and robotic procedures. In rectal surgery, robotics aims to overcome come technical limitations of laparoscopic approach tanks to better ergonomics and maneuverability of articulated instruments, allowing for a better visualization of surgical fields and an easier exposure of tissue plan and neurovascular elements[18].

In 5/15 patients, we perfomed new resection (re-do resection) respect to primary evaluation due to hypoperfusion documented by ICG use. Several studies have shown that ICG use during colorectal surgery has changed planning of bowel resection in 30 to 50% of patients and also reduced the anastomotic leak rate[19].

Other studies confirmed these data, reported that ICG use led to a change of planned bowel resection line in 13.9% (28/201) of cases. Use of ICG reduced AL in colorectal surgery by 4% compared with a control group[20].

In other studies, these data are confirmed in robotic surgery too[21].

In randomized controlled trials[22-23], in almost 7% of patients considered, the use of ICG resulted in a change of surgical strategy, meaning the resection line identified by the surgeon before the use of fluorescence was then reconsidered. In selected cases, a second evaluation was perfomed after the transaction, resulting in a re-resection due to un unsatisfying image. Fluorescence was important in the perfusion judgment, avoiding potential AL due to poorly perfused bowel stumps[18].

CONCLUSIONS

This study presents some limitations: study sample consists of 25 patients, so other patients must be enrolled in the future; other surgeons of Department of General Surgery with robotic expertise will be enrolled to overcome bias of single surgeon.

In Literature, there is no quantitative method for the analysis of the fluorescence signal, so it is impossible to compare results from various studies.

There is no consensus on the optimal dose of ICG or on the necessity of a second evaluation. ICG has a rapide diffusion to surrounding tissues and visualization can be difficult and it is a subjective criterion.

Finally, robotic surgery presents some costs for hospitals and surgical departments.

Despite costs associated with robotic surgery, numbers of interventions perfomed, reduced hospitalization and reduced complications related to mininvasive surgery produce a cost/effective balance.

Other studies are required to confirm early data obtained from our results.

TABLES

TABLE 1: PATIENTS CHARACTERISTICS

PATIENTS		25
AGE		67.2
MALE/FEMALE		14/11
BMI		26
ASA SCORE	ASA II	15
	ASA III	10
SMOKERS		2
HYPERTENSION		12
DIABETES MELLITUS		5
PATHOLOGY	-cancer	20
	-diverticular disease	5
CANCER LOCALIZATION	- rectal cancer	7
	- left colon cancer	8
	- right colon cancer	5
PRE-OPERATIVE CHEMO-RADIATION		7

TABLE 2: PROCEDURES AND RESULTS

OPERATIVE PROCEDURE	- robotic rectum anterior resection 7 - robotic left hemicolectomy 13 - robotic right hemicolectomy 5	
CONVERTION TO OPEN SURGERY	0	
ANASTOMOTIC LEAKAGE	0	
CHANGE OF LINE OF TRANSECTION	5	

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