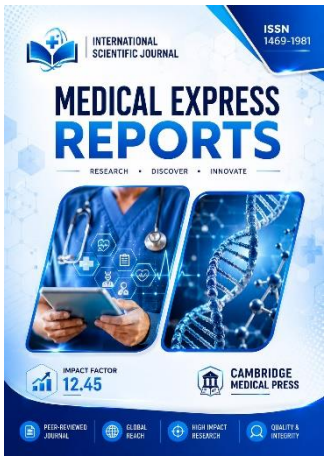
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THE SIGNIFICANCE OF MINIMALLY INVASIVE TECHNOLOGIES IN THE SURGICAL TREATMENT OF COLORECTAL CANCER

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ABSTRACT

This article analyses the role and significance of minimally invasive technologies in the surgical treatment of colorectal cancer. The evolution of the surgical approach from conventional open resection to laparoscopic, robot-assisted, transanal and endoscopic techniques is described, and the oncological principles of total mesorectal excision and complete mesocolic excision are examined. On the basis of the results of major randomized controlled trials (COST, COLOR, CLASICC, COLOR II, COREAN, ACOSOG Z6051, ALaCaRT, ROLARR), the short-term and long-term outcomes of minimally invasive and open surgery are compared. It is shown that minimally invasive surgery reduces postoperative pain, blood loss and length of hospital stay, accelerates the recovery of bowel function and, in experienced hands, provides oncological results equivalent to those of open surgery. The article also considers the criteria for patient selection, the importance of the learning curve, the enhanced recovery after surgery (ERAS) programme and promising directions such as fluorescence angiography and digital technologies..

Introduction. Colorectal cancer (CRC) is one of the most pressing problems of modern oncology and abdominal surgery. According to GLOBOCAN 2022 estimates, about 1.9 million new cases of colorectal cancer and more than 900,000 deaths from it were registered worldwide

in 2022; in terms of incidence it ranks third, and in terms of cancer mortality second, among all malignant tumours [1]. Incidence continues to rise in countries undergoing economic transition, which is associated with changes in diet, a sedentary lifestyle, obesity and population ageing. Uzbekistan is no exception to this trend, which makes the improvement of diagnostic and treatment methods for CRC a matter of great practical importance for national healthcare.

Despite the development of chemotherapy, radiotherapy and targeted therapy, surgical resection remains the only radical method of treating colorectal cancer, and the quality of the operation largely determines both the patient's survival and his or her quality of life. Over the past three decades, the surgical treatment of CRC has undergone a genuine revolution: alongside conventional open operations performed through a long midline laparotomy, minimally invasive technologies have become firmly established in clinical practice. The essence of minimally invasive surgery is to perform the same radical oncological operation while causing the least possible trauma to the patient's body.

The aim of this article is to analyse, on the basis of the scientific literature and the results of major clinical trials, the significance of minimally invasive technologies in the surgical treatment of colorectal cancer, their advantages and limitations, and the prospects for their further development.

Oncological principles of colorectal surgery. Any surgical technology, whether open or minimally invasive, is evaluated first and foremost by whether it allows the fundamental oncological principles to be observed. In rectal cancer surgery, the standard is total mesorectal excision (TME), proposed by R.J. Heald in 1982 [2]. Its essence is the sharp dissection of the rectum together with the entire mesorectum, which contains the lymph nodes and lymphatic vessels, within the embryological plane while preserving the integrity of the mesorectal fascia. The introduction of TME made it possible to reduce the rate of local recurrence substantially.

In colon cancer surgery, an analogous concept is complete mesocolic excision (CME) with central vascular ligation, described by W. Hohenberger and co-authors in 2009 [3]. Removal of the mesocolon in an intact fascial envelope, together with ligation of the supplying vessels at their origin, increases the number of harvested lymph nodes and improves long-term oncological results.

The main criteria for assessing the oncological quality of an operation are:

1. Circumferential resection margin (CRM): the absence of tumour cells within 1 mm of the circumferential margin of the specimen.

2. Distal resection margin: a sufficient distance from the lower edge of the tumour to the line of transection of the bowel.

3. Completeness of the mesorectum (mesocolon): the integrity of the fascial envelope as assessed by the pathologist.

4. Number of examined lymph nodes: at least 12 lymph nodes are required for adequate staging.

It is precisely by these criteria that minimally invasive technologies have been compared with open surgery in the major clinical trials.

Laparoscopic surgery. The first laparoscopic colectomy was reported by M. Jacobs and co-authors in 1991. In the early years, the method was received with caution: there were concerns about the adequacy of oncological radicalism, the risk of tumour implantation in trocar wounds (port-site metastases) and long operating times. These doubts were resolved through a series of multicentre randomized controlled trials.

A.M. Lacy and co-authors showed in a randomized trial that laparoscopic colectomy for non-metastatic colon cancer is accompanied by lower morbidity and a shorter hospital stay than open surgery, without any deterioration in cancer-related survival. In the American COST trial (872 patients), the rates of recurrence and overall survival after laparoscopic and open colectomy did not differ, while patients in the laparoscopic group had a shorter hospital stay and needed less analgesia [4]. The European COLOR trial confirmed the short-term advantages of the laparoscopic approach, and its long-term analysis showed no significant differences in three-year disease-free and overall survival. The British CLASICC trial also demonstrated comparable oncological results; at the same time, it drew attention to the relatively high rate of conversion to open surgery during the period when surgeons were still mastering the technique [5].

For rectal cancer, the key evidence was provided by the COLOR II and COREAN trials. In COLOR II, laparoscopic rectal resection was accompanied by less blood loss and faster recovery of bowel function, and the rate of locoregional recurrence at three years was the same (5.0%) in both groups [6]. The Korean COREAN trial, conducted in patients after neoadjuvant chemoradiotherapy, likewise showed equivalent short-term oncological quality and long-term disease-free survival.

At the same time, the ACOSOG Z6051 and ALaCaRT trials, published in 2015, did not confirm the non-inferiority of laparoscopic surgery with respect to a composite indicator of pathological quality (CRM, distal margin and completeness of TME) [7]. These results do not negate the value of laparoscopy, but they emphasize that the oncological safety of minimally invasive rectal surgery depends directly on the experience of the surgeon and the case volume of the centre, especially in the narrow male pelvis, in obese patients and with low-lying tumours.

The main advantages of laparoscopic surgery can be summarized as follows:

– less intensive postoperative pain and reduced need for opioid analgesics;

– less intraoperative blood loss;

– earlier recovery of bowel function and earlier resumption of oral feeding;

– shorter length of hospital stay and earlier return to normal activity;

– fewer wound complications and incisional hernias;

– a better cosmetic result and a lower rate of adhesions;

– magnified, high-definition visualization of anatomical structures, which facilitates the identification of embryological planes and autonomic nerves.

The disadvantages include longer operating time, high equipment costs, the limited range of motion of rigid instruments, the absence of tactile sensation and a long learning curve.

Robot-assisted surgery. Robotic surgical systems were developed to overcome the technical limitations of conventional laparoscopy. They provide a stable three-dimensional image controlled by the surgeon, instruments with articulated tips (seven degrees of freedom), tremor filtering and an ergonomic working position for the surgeon. These advantages are particularly valuable in the narrow pelvis, where precise dissection in the TME plane and preservation of the pelvic autonomic nerves are required.

The international randomized ROLARR trial compared robot-assisted and laparoscopic resection of rectal cancer. The rate of conversion to open surgery was lower in the robotic group (8.1% versus 12.2%), but the difference did not reach statistical significance; nor were significant differences found in CRM involvement or complication rates [8]. Subgroup analysis nevertheless suggested a possible benefit of robotic surgery in men and in obese patients. Thus, the robotic approach is regarded as a technically promising tool that facilitates complex pelvic operations, but its wider use is currently limited by high costs, and its advantages over laparoscopy in experienced hands require further confirmation.

Transanal and endoscopic technologies. For tumours of the lower third of the rectum, transanal total mesorectal excision (TaTME) has been developed, in which the mesorectum is dissected from below, through the anus, under endoscopic control. This provides better visualization of the distal resection margin and of the dissection plane in patients with a narrow pelvis. Data from the international TaTME registry showed satisfactory short-term results [9]; however, reports of an unusual, multifocal pattern of local recurrence in Norway after TaTME was introduced without structured training demonstrated that this technique should be performed only in specialized centres, with a proper training programme and auditing of results.

For benign neoplasms and early cancers (T1 tumours with favourable histological features), organ-sparing local excision is possible: transanal endoscopic microsurgery (TEM), transanal minimally invasive surgery (TAMIS) and endoscopic submucosal dissection (ESD). These methods allow the tumour to be removed en bloc while preserving the rectum, thereby avoiding a major abdominal operation and a stoma. Careful selection of patients and histological evaluation of the specimen are crucial: in the presence of unfavourable features (deep submucosal invasion, lymphovascular invasion, poor differentiation), radical resection is subsequently indicated.

Enhanced recovery after surgery. The full benefit of minimally invasive technologies is realized when they are combined with the enhanced recovery after surgery (ERAS) programme [10]. This multimodal approach includes preoperative patient education, the avoidance of prolonged fasting, carbohydrate loading, the rational use of drains and nasogastric tubes, opioid-sparing multimodal analgesia, goal-directed fluid therapy, early mobilization and early oral feeding. A small surgical trauma and an ERAS protocol reinforce each other, reducing the stress response of the body, the complication rate and the length of hospital stay.

Criteria for patient selection and the learning curve. Minimally invasive surgery is now regarded as the method of choice for most patients with resectable colon cancer and, in experienced centres, for rectal cancer. However, selection of the approach should take into account several factors:

1. Tumour factors: stage, size and location of the tumour, invasion of adjacent organs (T4b), the need for multivisceral resection.

2. Patient factors: body mass index, previous abdominal operations and adhesions, cardiopulmonary reserve and tolerance of pneumoperitoneum.

3. Surgical factors: the surgeon's experience, the number of operations performed in the centre and the availability of equipment.

4. Organizational factors: the presence of a multidisciplinary team (surgeon, oncologist, radiologist, pathologist, anaesthesiologist) and of a system for auditing results.

The learning curve deserves special attention. The quality of laparoscopic and robotic colorectal surgery stabilizes only after a certain number of operations have been performed, and outcomes during the mastering period may be inferior. For this reason, structured training programmes, simulation training, mentoring (proctoring) and video analysis of operations are of great importance for the safe introduction of minimally invasive technologies in regional hospitals.

Prospects for development. Minimally invasive colorectal surgery continues to develop rapidly. Fluorescence angiography with indocyanine green allows the perfusion of the bowel to be assessed intraoperatively before an anastomosis is formed; the PILLAR II study showed that the use of this method changed the surgical plan in a number of patients. Other promising directions include fluorescence-guided mapping of sentinel lymph nodes, three-dimensional and ultra-high-definition imaging systems, single-port and reduced-port surgery, new robotic platforms, augmented-reality navigation and artificial-intelligence-based systems for recognizing anatomical structures and assessing the quality of surgery from video recordings. These technologies are aimed at further increasing the precision and safety of operations and at standardizing their quality.

Conclusion. In conclusion, it should be emphasized that minimally invasive technologies have become an integral part of the modern surgical treatment of colorectal cancer. The results of major randomized trials show that laparoscopic surgery, while observing the principles of total mesorectal excision and complete mesocolic excision, provides oncological results comparable to those of open surgery, and at the same time reduces surgical trauma, postoperative pain, blood loss and the length of hospital stay, accelerating the patient's return to normal life.

Robot-assisted, transanal and endoscopic methods extend the possibilities of minimally invasive surgery in technically difficult situations and in early-stage tumours, but their effectiveness depends to a great extent on the surgeon's experience, careful patient selection and the organization of care. Consequently, the wider introduction of minimally invasive technologies into the practice of national healthcare requires the creation of specialized colorectal centres,

structured training programmes for surgeons, the implementation of ERAS protocols and multidisciplinary management of patients.

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