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Comparative effectiveness of robot-assisted and laparoscopic procedures in deep infiltrating endometriosis

Abstract

Relevance. The importance of the study is determined by the high prevalence of endometriosis among women of reproductive age and by the substantial negative effect of deep infiltrating endometriosis on the functional state of the pelvic organs, the quality of life of patients, and treatment outcomes. Despite the active development of minimally invasive gynaecological surgery, the choice of the optimal surgical approach for complex infiltrative forms of the disease remains debatable. An analysis of current scientific data on the effectiveness of robot-assisted and laparoscopic procedures is therefore especially relevant.

Aim. To summarise current scientific data on the use of robot-assisted and laparoscopic surgical procedures in deep infiltrating endometriosis and to analyse their clinical outcomes and features of use in minimally invasive gynaecological surgery.

Materials and methods. The study used methods of analysis, systematisation, and generalisation of current scientific sources devoted to the problem of surgical treatment of deep infiltrating endometriosis. The results of clinical studies, systematic reviews, and meta-analyses concerning the effectiveness and safety of robot-assisted and laparoscopic procedures were analysed. Approaches to analytical generalisation of perioperative indicators and clinical treatment outcomes were applied.

Results. Current approaches to the surgical treatment of deep infiltrating endometriosis were examined, and the role of laparoscopic and robot-assisted technologies in minimally invasive gynaecological surgery was determined. A generalisation of scientific data indicated that laparoscopic procedures remain the main method of surgical treatment for this pathology, whereas robot-assisted technologies broaden the possibilities for performing complex operations in cases of deep tissue infiltration and involvement of adjacent pelvic organs. It was established that, according to perioperative indicators such as intraoperative blood loss, complication rate, and length of hospitalisation, the results of both approaches were similar in most studies. Robotic systems may provide improved visualisation of the surgical field and greater precision of manipulation during treatment of complex anatomical localisations of the pathological process.

Conclusions. The analysis of the contemporary scientific sources indicated that the effectiveness of treatment for deep infiltrating endometriosis depends largely on the correct choice of surgical tactics and on individualisation of the surgical approach. Laparoscopic surgery remains the basic method of surgical treatment, whereas robot-assisted technologies should be used in complex clinical cases requiring high precision of surgical manipulation. The results obtained confirm the need for further accumulation of evidence on the long-term outcomes of different minimally invasive surgical technologies in deep infiltrating endometriosis.

Keywords: minimally invasive gynaecological surgery; pelvic pain syndrome; surgical tissue dissection; perioperative indicators; postoperative recovery.

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INTRODUCTION

Endometriosis is one of the most common gynaecological diseases among women of reproductive age and is characterised by a chronic course, complex pathogenesis, and a marked negative effect on reproductive health and the quality of life of patients. Deep infiltrating endometriosis is a particularly complex clinical form, accompanied by penetration of endometriotic lesions into deep tissue layers with involvement of the bowel, bladder, ureters, and other pelvic structures. The high frequency of pain syndrome, dysfunction of adjacent organs, and disease recurrence determines the need to improve approaches to the surgical treatment of this pathology. The active development of minimally invasive surgery has promoted the wide introduction of laparoscopic and robot-assisted technologies, but the choice of optimal surgical tactics for complex forms of the disease remains debatable.

The problem of surgical treatment for deep infiltrating endometriosis is extensively covered in modern scientific literature. H. Ong *et al.* [1], in a systematic review on the treatment of deep infiltrating endometriosis with bowel involvement, concluded that robot-assisted surgery is a safe and technically feasible treatment method that provides high precision of manipulation and improved visualisation of the surgical field in complex anatomical areas. M. Koteliukh [2], in turn, emphasised the importance of predicting clinical outcomes and using evidence-based approaches when choosing treatment tactics, which underlines the relevance of evaluating the long-term outcomes of modern surgical technologies. M. Cherniak & O. Korchynska [3] noted that, in widespread forms of endometriosis, surgical treatment is often the most effective way to eliminate symptoms and restore the functional state of the pelvic organs. A. Balan & L. Yurieva [4] stressed that deep infiltrating endometriosis is characterised by diagnostic complexity, considerable variability of clinical manifestations, and a high frequency of adjacent organ involvement, which requires an individualised approach to treatment. When comparing robotic and conventional laparoscopy for colorectal endometriosis, M. Le Gac *et al.* [5] indicated that both approaches produce similar clinical outcomes, whereas robotic surgery may provide additional technical advantages during complex surgical procedures.

A. Osaki & M. de Oliveira [6] specified that bowel or ovarian involvement substantially affects the duration of surgery regardless of the chosen surgical approach, which confirms the importance of careful preoperative planning and individualisation of surgical tactics. A meta-analysis of current publications by M. Pavone *et al.* [7] indicated that robot-assisted procedures are highly effective and safe, but they do not have substantial advantages over laparoscopic surgery for most perioperative indicators. Similar conclusions were reached by X. Zhang & X. Zhang [8], who demonstrated similar results for robotic and laparoscopic operations in colorectal endometriosis and the absence of important differences in the main clinical indicators. T. Hebert [9] noted that the use of robotic systems broadens the possibilities of minimally invasive surgery through improved surgeon ergonomics, three-dimensional visualisation, and high-precision instrument control during treatment of complex forms of deep infiltrating endometriosis. However, Á. Csirzó *et al.* [10], in a systematic review and meta-analysis, did not identify convincing evidence of substantial clinical advantages of robot-assisted surgery over conventional laparoscopy. The authors concluded that the available results remain heterogeneous, and that the evidence base needs further expansion through high-quality multicentre studies. Thus, the existing scientific studies confirm the prospects for using robotic technologies in the treatment of deep infiltrating endometriosis, while the question of their clinical advantages over conventional laparoscopy remains unresolved. The ambiguity of the results obtained, differences in study design, and the insufficient number of long-term clinical observations determine the need for further generalisation of current scientific data on the use of different minimally invasive surgical technologies.

This study aimed to analyse current scientific data on the effectiveness and safety of robot-assisted and laparoscopic surgical procedures in deep infiltrating endometriosis and to determine the features of their use in modern minimally invasive gynaecological surgery.

MATERIALS AND METHOD

The study was designed as a review of scientific literature concerning the use of laparoscopic and robot-assisted surgical procedures in deep infiltrating endometriosis. The literature search was conducted in the international scientometric and bibliographic databases PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar. Combinations of the following English-language keywords were used for the search: “deep infiltrating endometriosis”, “robot-assisted surgery”, “robotic surgery”, “laparoscopic surgery”, “minimally invasive gynecologic surgery”, “colorectal endometriosis”, “surgical treatment of endometriosis”, “robotic-assisted laparoscopy”, “perioperative outcomes”, and “clinical effectiveness”. The search used the Boolean operators AND and OR to broaden or refine the results.

The inclusion criteria for the review were: availability of the full text of the publication; relevance to the study topic; publication in peer-reviewed scientific journals; coverage of the results of laparoscopic or robot-assisted surgical procedures for endometriosis; and availability of data on clinical effectiveness, safety, perioperative indicators, or technical features of surgical performance. Systematic reviews, meta-analyses, clinical studies, randomised controlled trials, and

clinical trial protocols published mainly during 2020-2025 were included in the analysis. The exclusion criteria were duplicate publications, conference abstracts without full text, articles with insufficient description of treatment outcomes, studies devoted exclusively to drug therapy for endometriosis, and works that did not contain information on the use of laparoscopic or robot-assisted surgical technologies.

At the initial stage of the search, 86 publications were identified. After removing duplicates and analysing titles, abstracts, and full texts for compliance with the defined criteria, 20 of the most relevant sources were included in the final review. These sources directly concerned current approaches to the surgical treatment of deep infiltrating endometriosis and the comparison of laparoscopic and robot-assisted technologies. Methods of systematisation, critical analysis, comparison, and logical generalisation of scientific information were used to process the selected materials. Primary attention was given to the analysis of data on the technical characteristics of surgical procedures, perioperative outcomes, complication rates, length of hospitalisation, and features of postoperative recovery in patients. The results were generalised through a qualitative synthesis of the available evidence, with identification of common tendencies and discrepancies between studies. A meta-analysis was not performed in this study because of the heterogeneity of the available publications, differences in study design, characteristics of clinical samples, localisation of endometriotic lesions, and approaches to evaluating treatment outcomes. For this reason, the results obtained are presented as a qualitative review and analytical generalisation of current scientific data.

RESULTS AND DISCUSSION

In gynaecological surgery, treatment of deep infiltrating endometriosis is based on the use of minimally invasive surgical technologies that provide accurate removal of endometriotic lesions with minimal tissue trauma and preservation of the functional integrity of the pelvic organs. Laparoscopic surgery remains the most common method of surgical treatment and has formed the basis of minimally invasive gynaecology over recent decades. The development of high-technology medical equipment has also promoted the active introduction of robot-assisted tools, which open new prospects for performing complex surgical procedures in widespread forms of endometriosis. In clinical practice, these approaches are considered complementary elements of minimally invasive surgery, and the choice between them depends on the anatomical features of the lesion and the technical capacity of the medical institution (Table 1).

Table 1. Current surgical approaches to the treatment of deep infiltrating endometriosis in minimally invasive gynaecological surgery

Surgical approach	Main technological characteristics	Clinical significance in treatment
Conventional laparoscopic surgery	Use of laparoscopic instruments and a video-optical system for minimally invasive access	Provides effective removal of endometriotic lesions, reduces surgical trauma, and promotes faster postoperative recovery
Robot-assisted laparoscopic surgery	Three-dimensional visualisation of the surgical field and use of robotic instruments with high movement precision	Enables complex dissections in difficult-to-access anatomical areas and increases the precision of manipulation
Multidisciplinary minimally invasive procedures	Combined use of gynaecological, colorectal, and urological surgery	Provides comprehensive treatment of widespread forms of infiltrative endometriosis involving adjacent organs

Source: compiled by the author based on [3, 4, 9]

The choice of surgical technology is determined primarily by the anatomical localisation and depth of infiltration of endometriotic lesions. W. Huang *et al.* [11] stated that, when complex minimally invasive procedures are performed, the technical capabilities of the surgical system and the capacity to ensure precision of manipulation in difficult-to-access anatomical areas are decisive. Similar views were expressed by C. Alboni *et al.* [12], who considered robot-assisted surgery a promising direction for the treatment of widespread forms of deep infiltrating endometriosis involving adjacent pelvic organs. According to J. Hiltunen *et al.* [13], robot-assisted laparoscopy is a technically feasible and safe method for treating deep infiltrating endometriosis, especially when the pathological process is localised in the rectosigmoid area. Z. Song *et al.* [14], in a meta-analysis, reported that robotic and laparoscopic procedures demonstrated similar results for blood loss, complication rate, and length of hospitalisation in most studies.

M. Renso *et al.* [15] emphasised the need for randomised clinical trials to provide a more objective comparison of robot-assisted and laparoscopic approaches in the treatment of complex forms of endometriosis. A systematic review by S. Di Michele *et al.* [16] underscored that robotic technologies may be useful during reconstructive procedures on the urinary system because of the high precision of surgical manipulation. K. Kanno *et al.* [17] reported positive results from the use of robot-assisted nerve-sparing surgical procedures in deep endometriosis. E. Kivekäs *et al.* [18] also drew attention to the importance of

evaluating long-term clinical outcomes of minimally invasive technologies, as these outcomes provide an objective assessment of the effectiveness of the surgical approach. A meta-analysis by S. Restaino *et al.* [19] demonstrated that robotic and laparoscopic procedures are generally associated with similar clinical outcomes, while A. Terho *et al.* [20] stressed the need for further accumulation of evidence on the optimal choice of minimally invasive technology in severe forms of deep infiltrating endometriosis.

Thus, laparoscopic and robot-assisted technologies are considered complementary tools of modern minimally invasive surgery, and the choice between them is determined by the localisation of the pathological process, the complexity of the surgical procedure, and the technical capacity of a specialised medical centre. The clinical and surgical characteristics of robot-assisted and laparoscopic procedures in deep infiltrating endometriosis are based on the analysis of perioperative indicators that reflect the technical complexity of the operation, the level of intraoperative safety, and the rate of postoperative recovery in patients. The main parameters include duration of surgery, volume of blood loss, frequency of intraoperative complications, length of hospitalisation, and functional recovery. These indicators are used in clinical studies for the comparative evaluation of the effectiveness of different minimally invasive surgical technologies (Table 2).

Table 2. Perioperative clinical indicators for evaluating robot-assisted and laparoscopic procedures in deep infiltrating endometriosis

Perioperative indicator	Clinical characteristic	Practical significance for outcome evaluation
Duration of surgery	Time from the beginning of surgical access to completion of the main surgical stage	Reflects the technical complexity of the procedure and the efficiency of the surgical process organisation
Intraoperative blood loss	Volume of blood lost during surgery	Characterises the degree of tissue trauma and the precision of surgical manipulation
Frequency of intraoperative complications	Damage to vessels, bowel, bladder, or nerve structures	Enables assessment of the safety of the surgical technique
Length of hospitalisation	Number of days the patient remains in the hospital after surgery	Reflects the speed of postoperative stabilisation and recovery
Functional postoperative recovery	Restoration of bowel function, reduction of pain syndrome, and return to physical activity	Characterises the clinical effectiveness of treatment and the quality of rehabilitation

Source: compiled by the author based on [7, 8, 10, 14]

In contemporary clinical studies, perioperative indicators are considered the main criteria for evaluating the results of minimally invasive surgical treatment of deep infiltrating endometriosis. M. Pavone *et al.* [7] indicated that duration of surgery, intraoperative blood loss, and complication rate are among the most informative indicators when comparing robot-assisted and laparoscopic procedures. A similar approach was used by X. Zhang & X. Zhang [8], who, in their analysis of treatment outcomes in colorectal endometriosis, primarily evaluated blood loss, duration of surgery, and length of hospitalisation.

According to Á. Csirzó *et al.* [10], an important criterion of clinical effectiveness is not only the immediate result of surgery but also the rate of functional postoperative recovery. Z. Song *et al.* [14] reported that, in most of the analysed studies, blood loss, complication rate, and length of hospitalisation were similar for robotic and laparoscopic procedures. S. Restaino *et al.* [19] emphasised that treatment success is determined not only by the radicality of endometriotic lesion removal but also by the speed of recovery after surgery. A similar position was taken by A. Terho *et al.* [20], who stressed the need for standardised evaluation of both perioperative and long-term treatment outcomes. Thus, duration of surgery, intraoperative blood loss, complication rate, length of hospitalisation, and functional recovery remain key indicators for evaluating the effectiveness and safety of robot-assisted and laparoscopic procedures in deep infiltrating endometriosis.

Comparative evaluation of robot-assisted and laparoscopic procedures in deep infiltrating endometriosis is based on analysis of perioperative indicators that reflect the technical features of surgery, the level of intraoperative safety, and the dynamics of postoperative recovery. Taken together, the available studies indicate that both approaches are effective according to the main criteria, but they differ in the technological characteristics of surgical performance, which determines their appropriateness depending on the complexity of the anatomical localisation of the pathological process [3]. According to current scientific reviews, robot-assisted surgery provides more precise visualisation of the surgical field and greater instrument stability, which is important during resection of infiltrative lesions of the bowel or retrocervical space [12]. The results of meta-analyses also indicate that the overall clinical indicators of effectiveness of the two methods are mostly similar (Table 3).

Table 3. Comparative characteristics of the effectiveness and safety of robot-assisted and laparoscopic procedures in deep infiltrating endometriosis

Evaluation criterion	Robot-assisted surgery	Laparoscopic surgery
Visualisation of the surgical field	Three-dimensional, stable	Two-dimensional
Precision of surgical manipulation	High due to robotic instruments	Depends on the manual technique of the surgeon
Intraoperative blood loss	Low or similar	Low
Complication rate	Low in specialised centres	Low with sufficient surgeon experience
Postoperative recovery	Rapid	Similar to robotic procedures

Source: compiled by the author based on [7, 10, 12, 13]

Evaluation of the results of surgical treatment for deep infiltrating endometriosis extends beyond the purely technical characteristics of the surgical procedure. Current studies increasingly focus not only on the duration of surgery or the volume of blood loss but also on the rate of functional recovery in patients and their quality of life after treatment. M. Pavone *et al.* [7] indicated that duration of surgery, intraoperative blood loss, and complication rate are among the most informative criteria for evaluating the effectiveness of minimally invasive procedures. A similar approach was used by X. Zhang & X. Zhang [8], who, in their analysis of treatment outcomes in colorectal endometriosis, primarily evaluated blood loss, duration of surgery, and length of hospitalisation. The literature analysis suggests that isolated evaluation of separate perioperative indicators does not always provide an objective basis for determining the advantages of a particular surgical technology. In most studies, robotic and laparoscopic procedures demonstrate similar results for the main clinical parameters, whereas differences most often concern the technical aspects of surgical performance and the complexity of a particular clinical case [10, 14].

Evaluation of postoperative recovery in patients is especially important. The speed of return to usual physical activity, reduction of pain syndrome, and restoration of the function of adjacent organs largely determine the clinical effectiveness of treatment. This is emphasised by S. Restaino *et al.* [19] and A. Terho *et al.* [20], who stress the need for a comprehensive analysis of both immediate and long-term outcomes of surgery. A generalisation of study results reveals that the current tendency in the development of minimally invasive surgery for endometriosis lies not in opposing laparoscopic and robot-assisted technologies, but in identifying the most appropriate field of application for each approach depending on the clinical situation. Therefore, when evaluating the effectiveness of surgical treatment, it is appropriate to consider not only perioperative indicators but also the features of localisation of the pathological process, the complexity of the procedure, and the predicted functional outcomes. In the author's view, the choice of surgical tactics in deep infiltrating endometriosis should be based not only on the characteristics of the surgical technology but also on comprehensive consideration of the localisation of the pathological process, the functional state of adjacent organs, and the capacities of a specialised centre. A rational combination of laparoscopic and robot-assisted approaches can individualise treatment, improve the safety of surgery, and improve long-term clinical outcomes. The development of a multidisciplinary treatment model, which provides comprehensive management of patients with complex forms of the disease, is especially important.

CONCLUSIONS

1. It was established that minimally invasive surgical technologies form the basis of modern treatment for deep infiltrating endometriosis. Laparoscopic surgery remains the standard surgical approach due to its effectiveness and well-established technique, whereas robot-assisted technologies broaden the possibilities for performing complex operations in widespread infiltrative pelvic lesions.

2. A comparative analysis of clinical studies indicated that, according to the main perioperative indicators – blood loss, complication rate, and length of hospitalisation – the results of robot-assisted and laparoscopic operations are similar in most cases, although robotic systems may provide greater precision of manipulation in complex anatomical areas.

3. It was determined that the choice of optimal surgical tactics is difficult because of the technical complexity of operations in deep tissue infiltration, the variability of clinical outcomes, and the limited evidence base on the long-term effectiveness of robot-assisted procedures.

4. The appropriateness of an individualised approach to the choice of surgical technology was substantiated, considering the localisation of the pathological process, the clinical features of the disease, and the technical capacities of the medical institution.

The limitations of the study were its primarily review-based nature and the heterogeneity of the included clinical studies in terms of design, sample size, and criteria for outcome assessment. Further research should focus on multicentre clinical studies and the development of standardised algorithms for choosing minimally invasive surgical tactics in deep infiltrating endometriosis.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

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Порівняльна ефективність робот-асистованих та лапароскопічних втручань при глибокому інфільтративному ендометріозі

Анотація
Актуальність. Значущість дослідження зумовлена високою поширеністю ендометріозу серед жінок репродуктивного віку та суттєвим негативним впливом глибокого інфільтративного ендометріозу на функціональний стан органів малого таза, якість життя пацієнток і результати лікування. Незважаючи на активний розвиток малоінвазивної гінекологічної хірургії, питання вибору оптимального оперативного підходу при складних інфільтративних формах захворювання залишається дискусійним. Особливої актуальності набуває аналіз сучасних наукових даних щодо ефективності робот-асистованих і лапароскопічних втручань.
Мета. Узагальнити сучасні наукові дані щодо застосування робот-асистованих і лапароскопічних оперативних втручань при глибокому інфільтративному ендометріозі та проаналізувати їх клінічні результати й особливості використання в малоінвазивній гінекологічній хірургії.
Матеріали та методи. У роботі використано методи аналізу, систематизації та узагальнення сучасних наукових джерел, присвячених проблемі хірургічного лікування глибокого інфільтративного ендометріозу. Проведено аналіз результатів клінічних досліджень, систематичних оглядів і метааналізів щодо ефективності та безпеки робот-асистованих і лапароскопічних втручань. Застосовано підходи аналітичного узагальнення періопераційних показників і клінічних результатів лікування.
Результати. Проаналізовано сучасні підходи до хірургічного лікування глибокого інфільтративного ендометріозу та визначено місце лапароскопічних і робот-асистованих технологій у структурі малоінвазивної гінекологічної хірургії. Узагальнення наукових даних засвідчило, що лапароскопічні втручання залишаються основним методом оперативного лікування цієї патології, тоді як робот-асистовані технології розширюють можливості виконання складних операцій при глибокій інфільтрації тканин і залученні суміжних органів малого таза. Встановлено, що за такими періопераційними показниками, як інтраопераційна крововтрата, частота ускладнень і тривалість госпіталізації, результати обох підходів у більшості досліджень були співставними. Водночас роботизовані системи можуть забезпечувати покращену візуалізацію операційного поля та вищу точність маніпуляцій під час лікування складних анатомічних локалізацій патологічного процесу.
Висновки. Аналіз сучасних наукових джерел засвідчив, що ефективність лікування глибокого інфільтративного ендометріозу значною мірою залежить від правильного вибору хірургічної тактики та індивідуалізації оперативного підходу. Лапароскопічна хірургія залишається базовим методом оперативного лікування, тоді як робот-асистовані технології доцільно використовувати у складних клінічних випадках, що потребують високої точності хірургічних маніпуляцій. Отримані результати підтверджують необхідність подальшого накопичення доказової бази щодо довгострокових результатів застосування різних малоінвазивних хірургічних технологій при глибокому інфільтративному ендометріозі
Ключові слова: малоінвазивна гінекологічна хірургія; тазовий больовий синдром; хірургічна дисекція тканин; періопераційні показники; післяопераційне відновлення.