DOI: 10.1111/tog.12947
The Obstetrician & Gynaecologist
http://onlinetog.org

Review

Surgical techniques for ovarian endometriosis

Alexandros L Grammatis MD PhD MSc FHEA MRCOG,*[a] **Alexandros Lazaridis** MD MRCOG MSc BSCCP,[b,c] **Christian M Becker** MD,[d] **Ertan Saridogan** MD PhD MRCOG[e]

[a]Department of Obstetrics and Gynaecology, Oxford University Hospitals NHS Trust, Oxford OX39DU, UK
[b]Second Department of Obstetrics and Gynaecology, Aretaieion Hospital, Faculty of Medicine, National and Kapodistrian University of Athens, Athens 11528, Greece
[c]St. Mary's Hospital, Imperial College NHS Trust, London W2 1NY, UK
[d]Nuffield Department of Women's & Reproductive Health, University of Oxford, Oxford OX39DU, UK
[e]Elizabeth Garrett Anderson Institute for Women's Health and Consultant in Reproductive Medicine and Minimal Access Surgery, Women's Health Division, University College London Hospital, London NW12PG, UK
*Correspondence: Alexandros L Grammatis. Email: alexgrammatis@gmail.com

Accepted on 17 July 2024.

Key content

- All patients with ovarian endometriosis should be offered an individualised, shared decision-making approach informed by clinical history, symptoms and fertility status.
- Surgical management of ovarian endometriosis can be effective in treating endometriosis-associated pelvic pain and infertility, but there is no current evidence that surgery for ovarian endometriosis increases the success of in vitro fertilisation (IVF) treatment.
- Ovarian reserve tests should be considered before any ovarian surgery and can help guide the patient towards the optimal treatment.
- The Endometriosis Fertility Index should be incorporated into pre-operative consultations as a validated tool that estimates the likelihood of spontaneous conception following surgical intervention.
- Surgeons should be trained in different surgical techniques, types of diathermy and haemostatic agents that can minimise the risk of inadvertent injury to normal ovarian cortex.

Learning objectives

- To facilitate informed decision-making regarding the treatment of ovarian endometriosis.
- To gain insight into the possible surgical techniques available to manage ovarian endometriosis and the evidence behind them.
- To understand the impact of each technique on endometriosis-associated pain, fertility outcomes and recurrence rates.

Ethical considerations

- Should fertility preservation be offered to all women of reproductive age with fertility aspirations and a diagnosis of endometriomas?
- Should integrated care boards (ICBs) devise specific criteria to offer funding for fertility preservation as an option before surgery for ovarian endometriosis?

Please cite this paper as: Grammatis AL, Lazaridis A, Becker CM, Saridogan E. Surgical techniques for ovarian endometriosis. *The Obstetrician & Gynaecologist* 2024; https://doi.org/10.1111/tog.12947

Introduction

Endometriosis is a common hormonally driven inflammatory condition with a prevalence of 6–10% in women of reproductive age.[1] Many people with endometriosis experience cyclical and non-cyclical pain symptoms.[2] Moreover, 30–50% of women with endometriosis can present with subfertility.[3] Currently, endometriosis is surgically subdivided into three different entities, which are frequently found together: peritoneal lesions, deep endometriosis and ovarian endometriotic cysts (endometriomas).[4]

Surgical management of ovarian endometriosis can be effective in treating endometriosis-associated pelvic pain and infertility but can also have a detrimental effect on the ovarian reserve and is associated with significant recurrence rates.[5,6] Therefore, the right indication for surgery and the type of procedure must be decided on an individual basis. A patient's wishes and priorities should be established and she needs to be informed of the potential benefits and risks based on the available evidence. Alternative management options including conservative surveillance or medical approaches need to be discussed by health professionals experienced in both endometriosis and fertility.

This article aims to summarise the evidence behind each surgical technique aimed at treating ovarian endometriosis and their effect on the treatment of pelvic pain, impact on ovarian reserve and association with recurrence rates.

Patient selection

A detailed conversation with the patient pre-operatively can help the clinician choose the correct management and serve as a prompt to arrange the necessary pre-operative investigations that can help address treatment expectations.

Prior to being offered surgery to treat ovarian endometriosis, the patients should be categorised according to their clinical history, symptoms and fertility status, bearing in mind that some recommendations might overlap between groups:

1. Symptomatic patient with infertility
2. Asymptomatic patient with infertility
3. Symptomatic patient without current fertility aspirations
4. Symptomatic patient with future fertility aspirations
5. Asymptomatic woman without current fertility aspirations
6. Asymptomatic woman with future fertility aspirations

When making individualised reproductive plans for women with endometriomas and history of infertility, it is important to take into consideration the patient's age, previous surgeries, size and laterality of the endometrioma(s) and ovarian reserve tests such as anti-Müllerian hormone (AMH) and antral follicle count (AFC), as well as coexistent aetiologies for subfertility, including tubal status (if known) and semen parameters in the male partner. The latter is quite pertinent: according to the updated 2022 European Society of Human Reproduction and Embryology (ESHRE) guidelines, when there is a clear indication for assisted reproductive treatment (ART) then surgical treatment prior to ART is obsolete, unless there is a desire to manage endometriosis-associated pain or to improve accessibility to the ovaries.[7] Hence, the patient needs to have a frank discussion with the clinician regarding what their main priority at that moment in time is, the treatment of pain or subfertility.

Symptomatic patient with infertility

Surgical treatment may be beneficial both for endometriosis-associated pain and infertility. In cases where patients opt for surgical treatment, the aim should be to excise all visible endometriotic lesions and normalise the pelvic anatomy to effectively manage the endometriosis-associated pain but use conservative techniques to treat the endometrioma, as we will discuss in the next section. Despite the absence of good-quality evidence, the current guidance is that operative laparoscopy can be considered for the management of endometrioma-associated infertility, as it may increase the likelihood of spontaneous conception. However, it is important to acknowledge the absence of comparative data from controlled studies.[7] Prospective data have shown that post-operative pregnancy rates range from 30 to 67%, with a mean rate of 50%.[8] Maggiore et al.[9] in their retrospective analysis indicated that the crude and cumulative spontaneous pregnancy rates were higher in those treated surgically compared with expectant management in women with rectovaginal endometriosis with or without endometriomas (30.4% and 34.5% versus 11.7% and 18.0%, respectively). In another retrospective analysis, surgical treatment of endometrioma-associated infertility resulted in spontaneous pregnancy rates of 54.2%.[10]

While surgical treatment of endometriomas might increase spontaneous pregnancy rates, the current evidence suggests that it does not increase ART success rates and might be detrimental. This is due to several reasons. Initially, surgery and the need for postoperative recovery can delay the start of in vitro fertilisation (IVF) treatment. Additionally, iatrogenic collateral damage to the ovarian cortex or vasculature can compromise the ovarian reserve,[5,11] leading to fewer oocytes and the requirement for a higher dose of gonadotrophins. Conversely, patients should be counselled that the size of the endometrioma is an important factor that can affect the response to ovarian stimulation in the affected gonad,[12,13] although there is no clear evidence that surgical treatment can alter these outcomes. Hence, there is considerable uncertainty whether operating on an endometrioma prior to IVF is beneficial or not.[14]

Garcia-Velasco and Somigliana[15] have produced a helpful table to facilitate discussions of when surgical treatment might be considered prior to starting ART. We have modified this table for the purposes of this article (Table 1).

Asymptomatic patient with infertility

For this group, the cause and duration of infertility needs to be established. Options of surgery, ART and expectant management would be applicable to this group of women depending on their individual circumstances. As mentioned above, data from retrospective studies suggest surgery can increase spontaneous pregnancy rates. If there is a clear indication for ART such as severe male factor or bilateral tubal damage, the patient needs to be directed towards that option. As previously discussed, laparoscopic removal of endometriomas before IVF does not demonstrably improve fertility outcomes. Indeed, good-quality evidence suggests a potential reduction in responsiveness to gonadotrophins following ovarian cystectomy, with no observed improvement in the number and quality of oocytes retrieved,[16,17] while IVF or ICSI do not appear to have a negative impact on endometriosis symptoms or its progression or recurrence.[18,19] Thus, our clear recommendation in this group of patients, based on current evidence, is to proceed directly to IVF to optimise time to pregnancy, minimise risks associated with surgery and reduce associated patient costs.

Table 1. Clinical variables to be considered when deciding whether or not to perform surgery in women with endometriomas and history of infertility

Factors	Favours surgery	Favours ART
Previous interventions for endometriosis	None	≥1
Ovarian reserve [a]	Normal	Reduced
Pain symptoms	Present	Absent
Laterality	Unilateral disease	Bilateral disease
Atypical sonographic features [b]	Present	Absent
Growth	Rapid growth	Stable
Infertility duration	Short	Long
Patient's intentions and priorities	Patient choice [c]	Patient choice [c]

Abbreviations: ART = assisted reproductive treatment. [a]Ovarian reserve is estimated based on serum and ultrasound markers or previous hyperstimulation cycles. [b] Atypical sonographic features raising possibility of malignancy refer to solid components, locularity, echogenicity, regularity of shape, wall, septa, location and presence of peritoneal ascites. [c] Influenced by culture, religion, educational level and the healthcare system. Reproduced with permission but modified.[15]

In cases when there is either no clear indication for ART (e.g. a young patient with a short history of infertility) or the patient does not agree to it, conservative management should also be offered, although the discussion becomes more nuanced. Age is an important factor and young women with regular menstrual cycles can be counselled towards natural conception, before considering surgical approach or fertility treatment. Despite limited data on the specific impact of endometriomas on spontaneous conception, a prospective cohort study reported a 43% pregnancy rate within a 6-month follow-up period for women with unilateral endometriomas of varying sizes (mean diameter: 5.3 ± 1.7 cm). Notably, the study also observed similar ovulation rates between the affected and healthy ovaries (49.7% versus 50.3%), regardless of endometrioma laterality, number, size or the presence of co-diagnosed deep endometriosis via ultrasound.[20] Conversely, for women with naturally or treatment-induced diminished ovarian reserve, a cautious approach to fertility management is essential to weigh the potential risks and benefits of surgical intervention versus fertility treatment options.[21]

The Endometriosis Fertility Index (EFI) has emerged as a tool to estimate the probability of natural conception following surgical intervention for endometriosis.[22] Shi et al. demonstrated that a higher prevalence of peritoneal and ovarian endometriosis is associated with a diminished live birth rate (LBR) and reported a positive correlation between a high post-operative EFI score and LBR in this group.[23] More recently, it was noted that the EFI can be reliably and reproducibly measured non-invasively with the use of ultrasound.[24] This is a useful adjunct to the clinician's armory to guide patients towards surgery or fertility treatment.

Symptomatic patient without current fertility aspirations

With regards to treating endometriosis-associated pain, surgical treatment is one of the options that can be offered to patients, although there is a lack of randomised controlled trials (RCTs) comparing cystectomy with no intervention in women with endometrioma and estimating the effect on pain symptoms.[7] Laparoscopy facilitates a comprehensive evaluation and treatment of the pelvis and peritoneal cavity. This includes the assessment and management of superficial and deep endometriosis, tubal abnormalities and pelvic adhesions. Notably, the presence of a sonographically identified endometrioma is frequently accompanied by pelvic adhesions (73%) and endometriotic implants or adenomyosis (85%).[25] Presence of endometrioma is also considered a marker for deep endometriosis.[25] Complete excision of the endometriotic lesions with restoration of pelvic anatomy represents a cornerstone in the management of endometriosis-associated pain, and it can also help to preserve the long-term reproductive potential. Additionally, the surgical approach facilitates definitive diagnosis via histopathological examination and the exclusion of ovarian malignancy. We will expand on the appropriate surgical techniques for this group in the next section.

Medical management of endometriosis-associated pain and post-operative hormonal treatment to prevent recurrence – with the notable addition of the PRE-EMPT trial results to the literature[26] – should also be discussed as options, but they fall outside the remit of this review.

Symptomatic patient with future fertility aspirations

Similar to the previous group, surgical and medical treatment of ovarian endometriosis should be discussed, with an emphasis on the potential impact of surgery on the ovarian reserve. It is also important to reiterate that currently we do not have evidence that surgery would result in better future fertility in women who have not tried for pregnancy yet. Increased spontaneous pregnancy rates following surgery apply only to women with a history of infertility.

Prognostic factors to predict reduced or diminished post-operative ovarian reserve should be evaluated prior to proceeding with surgical treatment for endometriomas. Preoperative AMH levels could be a biomarker to benchmark ovarian reserve after surgery.[16] A systematic review and meta-analysis reported a median preoperative AMH level of 3.1 ng/mL, which significantly declined to 1.51 ng/mL within 1 to 9 months postoperatively.[11] The reduction of serum AMH levels is more pronounced in women with bilateral endometriomas compared with those with unilateral disease.[17] Furthermore, for patients requiring IVF treatment, existing evidence suggests that women diagnosed with poor ovarian response, as defined by the Bologna criteria,[27] following laparoscopic cystectomy for endometriomas exhibit significantly lower pregnancy and live birth rates compared with those with primary poor ovarian response.[28] Interestingly, longitudinal studies with a 12-month postoperative follow-up period indicate a biphasic pattern in AMH levels. While levels demonstrably decrease 1 month after surgery, a gradual increase is observed at 3 and 6 months, often leading to complete recovery by 12 months, with persistent reduction only in the bilateral endometrioma group.[29,30] There are several hypotheses explaining the delayed recovery of AMH, focusing mainly on the stimulation of follicular differentiation after partial burning of ovarian tissue and the 180-day duration of folliculogenesis.[31,32]

In cases where preoperative evaluation suggests compromised ovarian reserve or a significant risk of premature ovarian insufficiency, fertility preservation strategies should be explored prior to cystectomy. Somigliana et al.[33] and Carillo et al.[34] state in their respective opinion papers that fertility preservation may be particularly warranted for patients with bilateral ovarian endometriomas or those with a history of previous unilateral endometrioma cystectomy with a subsequent contralateral recurrence.[33,34] For postpubertal women, established fertility preservation techniques include oocyte or embryo cryopreservation following controlled ovarian stimulation (COS) to facilitate subsequent IVF with embryo transfer.[35] However, disadvantages associated with pre-cystectomy fertility preservation include postponement of surgery, the risk of visceral injury during oocyte retrieval, pelvic infection arising from inadvertent cyst puncture[36] and a theoretical elevation in the risk of ovarian torsion secondary to COS. The lack of NHS funding for fertility preservation for non-cancerous conditions has to be part of the conversation here. Individual funding requests might be accepted in cases when there is high risk of permanent subfertility, such as previous oophorectomy or repeated surgery for ovarian endometriosis.[37] Of note, fertility preservation should ideally be offered to those at a younger age than 35 years to increase the likelihood of success.[38]

Asymptomatic woman without current fertility aspirations

Conservative treatment should be discussed here, as well as medical and surgical management, with the caveat that the development and natural progression of endometriomas are not fully researched. However, a recent study on the natural progression of ovarian endometriosis was reassuring.[39] Patients should be reassured that the risk of spontaneous endometrioma rupture is a rare occurrence.[40] Clinicians should be aware of the risk factors linking endometriomas with ovarian cancer, particularly in cases when long-term conservative management is followed. These include the size of the endometrioma, specifically sizes over 9 cm, postmenopausal status and the presence of solid components, with the caveat that in women who are 45 years or older the incidence of endometriomas containing blood clots that can mimic solid components increases in prevalence.[41-43]

Asymptomatic woman with future fertility aspirations

While conservative treatment and follow-up visits to check the size of endometrioma and the symptoms of the patient are usually the first-line option, a discussion should be had about the long-term effect of endometriomas on ovarian reserve. This is probably mediated through tissue oxidated stress leading to fibrosis; toxic agents, such as free iron, diffusing through the endometrioma wall; and mechanical stretching of the ovarian cortex.[44] Hence, both surgical intervention and continued presence of endometrioma carry potential risks to nearby healthy tissue.

However, it also needs to be clarified that reduced surrogate markers of ovarian reserve do not predict spontaneous conception, provided that the remaining follicular pool is sufficient to ensure regular ovulation.[45,46] Furthermore, the previously described data regarding the increase of spontaneous conception after treatment of ovarian endometriosis refer only to patients with a history of infertility; it is unclear if applying the same approach to women without proven infertility would be effective or even advisable. Lastly, similar to the symptomatic group, the same principles regarding ovarian cryopreservation prior to cystectomy should be discussed with the patient if they opt for a surgical approach.

Surgical techniques

The management of endometriomas encompasses a spectrum of surgical approaches, each offering a distinct risk-benefit

Table 2. Surgical procedures for endometriomas

Technique	Potential risks and limits	Advantages
Ovarian cystectomy	Detrimental to ovarian reserve, particularly in cases of large endometriomas.	Most effective against endometriosis-associated pain. Lower risk of recurrence compared to other techniques.
Drainage and use of electroagulation	High risk of cyst and symptom recurrence, detrimental to adjacent normal ovarian tissue.	Preserves ovarian function. Can be considered prior to ART to improve accessibility of ovaries.
Drainage and use of CO_2 laser	Less effective than cystectomy to manage endometriosis-associated pain. Difficult to use in multiple endometriomas as reduced tissue penetration depth. Equipment cost. Risk of recurrence may be higher.	Preserves ovarian function. Comparable increase in spontaneous pregnancy rates to cystectomy. Less thermal injury to adjacent normal ovarian tissue than electrocoagulation.
Drainage and use of PlasmaJet	Not enough evidence regarding pain and fertility outcomes. Equipment cost.	Theoretically preserves ovarian function. Less thermal injury to adjacent normal ovarian tissue than electrocoagulation.
Alcohol sclerotherapy	High risk of cyst and symptom recurrence. No agreed concentration and duration of retention.	Preserves ovarian function. Suitable as pre-ART procedure. Can potentially be performed by fertility experts transvaginally, although thick endometrioma fluid may limit its feasibility.
Oophorectomy	Radical treatment, can cause premature ovarian insufficiency and associated risks if done bilaterally.	Definitive treatment for endometriosis-associated pain for patients without fertility aspirations.
Cystectomy with combined approach	Not enough evidence regarding pain and fertility outcomes. Equipment cost.	Potentially combines benefits of ovarian cystectomy and CO_2 laser.

Abbreviations: ART = assisted reproductive treatment.

profile. The pros and cons of each technique are summarised in table 2.

Ovarian cystectomy

Ovarian cystectomy aims at complete removal of the cyst capsule. Mobilisation of the affected ovary, which is commonly adherent to the pelvic side wall, usually leads to drainage of cyst contents. If the cyst does not drain, an incision is made on the antimesenteric border to drain the contents while avoiding blood vessels in the hilum. The path of the ureter is then identified. Following this, the most important step is to identify the cleavage plane. This might be achieved by making an incision either on the edge of the cyst where it spontaneously ruptures during the previous manipulation or at the base of the cyst to divide the cyst into two halves. With both approaches, the incision should be away from the blood vessels in the hilum/meso-ovarium. Once the cleavage plane is identified, gentle traction and counter-traction with an atraumatic grasper holding the healthy ovarian stroma and a traumatic grasper holding the cyst wall should be used to separate the cyst capsule from the ovarian parenchyma with minimal use of electrosurgery for selective haemostasis with bipolar energy at a low setting. Alternatively, blunt dissecting techniques can be utilised with hydro-dissection. Excessive force to divide highly adherent parts of the cyst should be avoided, as it can cause tearing of ovarian tissue and excessive bleeding, leading to inappropriate use of diathermy and damage to or loss of normal ovarian tissue.[47]

Cyst walls of small size may be directly fragmented and retrieved via a laparoscopic port, whereas larger cyst wall specimens necessitate extraction via a retrieval bag.[47] Surgical techniques that include minimising abdominal wall contact, utilising retrieval bags and using abdominal lavage at the end of the procedure while the trocars are still in place may reduce the risk of port-site endometriosis, although it is a rare complication.[48]

The updated ESHRE guidelines recommend ovarian cystectomy as the preferred surgical intervention for endometriomas compared with drainage and coagulation, based on evidence demonstrating a lower risk of recurrence and a greater likelihood of spontaneous pregnancy following cystectomy, particularly for cysts exceeding 3 cm in diameter.[7] A Cochrane systematic review by Hart et al. summarised the findings of two RCTs which demonstrated better outcomes of excisional surgery over

drainage and coagulation of an endometrioma in achieving a spontaneous pregnancy among subfertile women, as well as fewer cyst recurrences and lower likelihood of further surgery and development of non-cyclical pain.[49]

Nevertheless, stripping and removing the cyst wall can lead to loss of healthy collateral ovarian tissue. Muzii et al.[50] analysed histological specimens following ovarian cystectomy and found that in 54% of cases some ovarian cortex was excised along with the endometriotic cyst, as opposed to 6% in non-endometriotic cysts, albeit the tissue was found to be non-functional in the majority of cases.[50] This is supported by the possible pathogenesis of endometriomas. It is widely believed that they start from a deposit of endometrium through the fallopian tube,[51] causing adherence of the ovary to the pelvic side wall peritoneum and progressive invagination of the ovary, [52] but this is contentious and may not apply to all endometriomas. If this is plausible, then an endometrioma is a pseudocyst, the wall of which is the inverted ovarian cortex. Hence, any attempt to fully excise it will result in removal of normal ovarian tissue.[53]

The size of the cyst being removed is another important factor, and we have already discussed how it can affect responsiveness to ovarian stimulation.[12,13] Using histological measurements, Roman et al.[54] found an average loss of 200 μm thickness of ovarian tissue per centimetre increase in endometrioma diameter. Bilateral cystectomy can also lead to a greater decline in ovarian reserve than unilateral surgery,[55] and a 2.4% risk of premature ovarian insufficiency, which needs to included in the pre-operative discussion.[56]

Due to this issue, when there is extensive fibrosis and cyst wall induration leading to challenging surgical planes, alternative approaches have been proposed, such as partial cystectomy and cauterisation of the remaining cyst wall.[57] However, these are associated with an increased risk of recurrence due to incomplete cystectomy. Finally, novel techniques include the 'water injection' technique.[58] This technique has the benefit of minimising tissue destruction during separation and improving visualisation with the use of Vasopressin injected (0.1–1 unit/ml) under the cyst capsule. Of note, and although rare, Vasopressin may cause intraoperative cardiovascular complications including bradycardia and hypertension.[47]

Figure 1 demonstrates ovarian cystectomy of an endometrioma.

Drainage with cauterisation/ablation using electrocoagulation

Another surgical intervention is cyst drainage, where the cyst is aspirated laparoscopically or through a transvaginal needle under ultrasound guidance. Isolated cyst aspiration is rarely performed as recurrence is frequent and can approach 100%.[59,60] The laparoscopic approach is usually preferred as it offers the opportunity for tissue biopsy and the use of targeted electrocoagulation on the cyst wall. The technique aims to preserve ovarian function and minimise thermal trauma caused by electrosurgical haemostasis of stromal vessels. However, simple coagulation would result in the persistence of ectopic endometrium and an increase in the chance of cyst recurrence.[61] In addition, extensive use of energy can cause loss of primordial follicles, and surgeons are advised to use it selectively in a systematic approach. Bipolar energy results in less thermal spread and a setting of 20–30 W is commonly used.[47] Owing to the high risk of cyst and symptom recurrence, this technique is not frequently used to treat endometriosis-associated pain and if it is, is usually combined with post-operative hormonal treatment.

Drainage with cauterisation/ablation using CO_2 laser

CO_2 laser has been utilised in gynaecology with advantages when compared with other energy modalities, as it facilitates surgeons to vaporise pathological tissue with high precision owing to reduced tissue penetration depth and minimal thermal spread to surrounding healthy tissue. The surgical procedure typically involves opening, draining, and irrigating the cyst, followed by a tissue biopsy. Subsequently, the cyst wall is everted, and the CO_2 fibre laser vaporises the cyst's inner lining. An RCT comparing CO_2 laser with cystectomy demonstrated a significant increase in AFC in patients treated with the CO_2 laser, with no observed decrease in serum AMH levels. Conversely, the cystectomy group experienced a significant reduction in both parameters. Notably, the study found comparable pregnancy rates following both treatment modalities.[62] Overcoming the equipment costs and trained theatre staff limitations, this technique is simple and reproducible, possibly requiring less surgical dexterity and experience.[63]

Drainage with cauterisation/ablation using PlasmaJet

Although there is a lack of published data regarding the isolated use of the advanced energy device PlasmaJet for the surgical management of ovarian endometriosis, the lack of lateral thermal spread around the jet of plasma that makes the dissection safe and precise, as well as the ablative property, means it offers a possible alternative to cystectomy. Observational controlled studies have shown promising results, but RCTs are needed to be able to draw definitive conclusions.[64]

Alcohol sclerotherapy

Cyst drainage can be further combined with a procedure known as sclerotherapy. This technique involves instillation of a sclerosing agent into the cyst cavity following laparoscopic or transvaginal drainage. Methotrexate, tetracycline and ethanol are among the sclerosing agents that have been investigated in this context.[65] The proposed mechanism of action for sclerotherapy involves disruption of

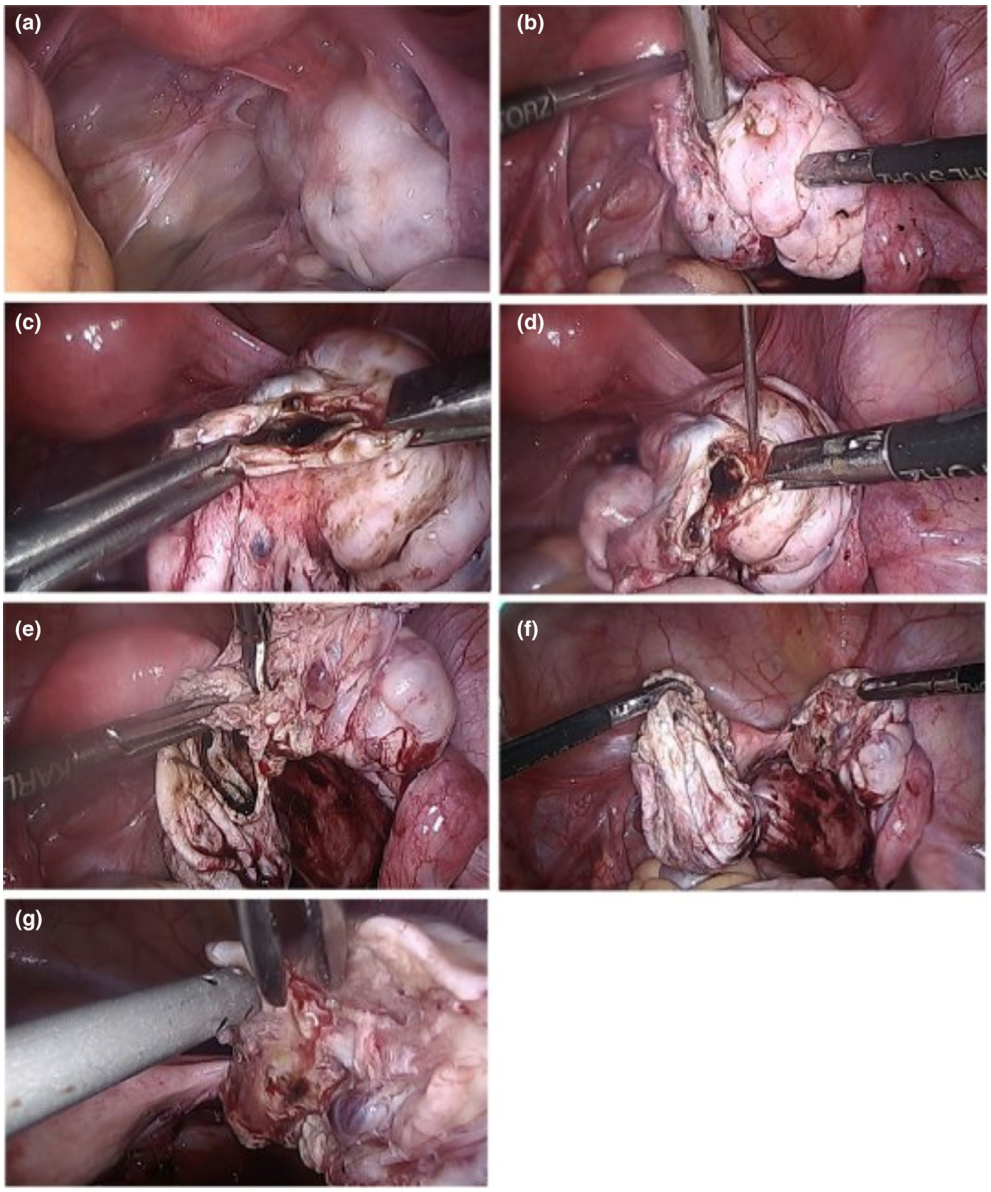

Figure 1. Ovarian cystectomy of an endometrioma. (a) Right ovarian endometrioma and adherent right ovary. (b) Drainage of endometrioma after mobilising the ovary. (c) Exposure of the plain between the cyst wall and ovarian cortex. Cyst wall grasped with either traumatic or atraumatic forceps and ovarian cortex handled all the time with the atraumatic one. Traction and countertraction applied. (d) Vasopressin injection under the cyst capsule. (e) Dissection of cyst capsule from the ovarian parenchyma. (f) Cyst capsule after complete removal. (g) Precise spot bipolar diathermy to achieve haemostasis.

the cyst's epithelial lining, triggering inflammation and subsequent fibrosis, ultimately leading to cyst obliteration. A systematic review by Cohen et al.[65] reported a broad range of endometrioma recurrence rates following sclerotherapy, ranging from 0% to 62.5%, and highlighted a higher risk of recurrence in women treated with ethanol lavage compared with those undergoing ethanol retention.[65] While the concentration and duration of ethanol washing and retention vary, the most common formulation is sterile 100 % pure ethanol, dispensed from a 10-ml vial. The volume of ethanol utilised should correspond to two-thirds of the aspirated endometrioma content, excluding any serum lavages. The total volume employed should ideally not exceed 100 ml. The instilled ethanol remains within the cyst cavity for a period of approximately 15 minutes before subsequent evacuation. The cavity is then thoroughly irrigated with saline solution until complete dryness is achieved.[66] A key finding for infertile patients who later

need IVF treatment and have undergone sclerotherapy is that the procedure yielded a higher number of oocytes retrieved compared to laparoscopic cystectomy, while clinical pregnancy rates remained comparable between the two groups. Conversely, no significant difference was observed in the number of oocytes retrieved or clinical pregnancy rates when comparing sclerotherapy with no treatment.[65] The findings of that review were further validated by a more recent prospective multicentre pilot cohort study, in which alcohol sclerotherapy was shown to preserve fertility in patients with endometriomas better than ovarian cystectomy, with significant increases in serum estradiol concentrations, post-operative AFC levels and spontaneous pregnancy rates.[66] Still, long-term data on the effect of different sclerotherapy agents on ovarian function and reserve are needed.

Combined approach

Investigative efforts have explored hybrid approaches that combine several of the aforementioned techniques. Donnez et al.[67] proposed a three-stage surgical strategy for endometrioma management with the objective of minimising ovarian tissue damage. This approach involves a first laparoscopy limited to cyst content drainage, irrigation and cyst wall biopsy. Subsequently, a gonadotrophin-releasing hormone (GnRH) agonist is administered for a 3-month period to achieve a reduction in cyst diameter, diminish stromal vascularisation and decrease the mitotic activity of endometriotic glands. After a 12-week interval, a second laparoscopy is performed to vaporise the inner cyst wall using a CO_2 laser. The prospective study by Donnez et al. compared this three-stage technique with a single laparoscopic cystectomy

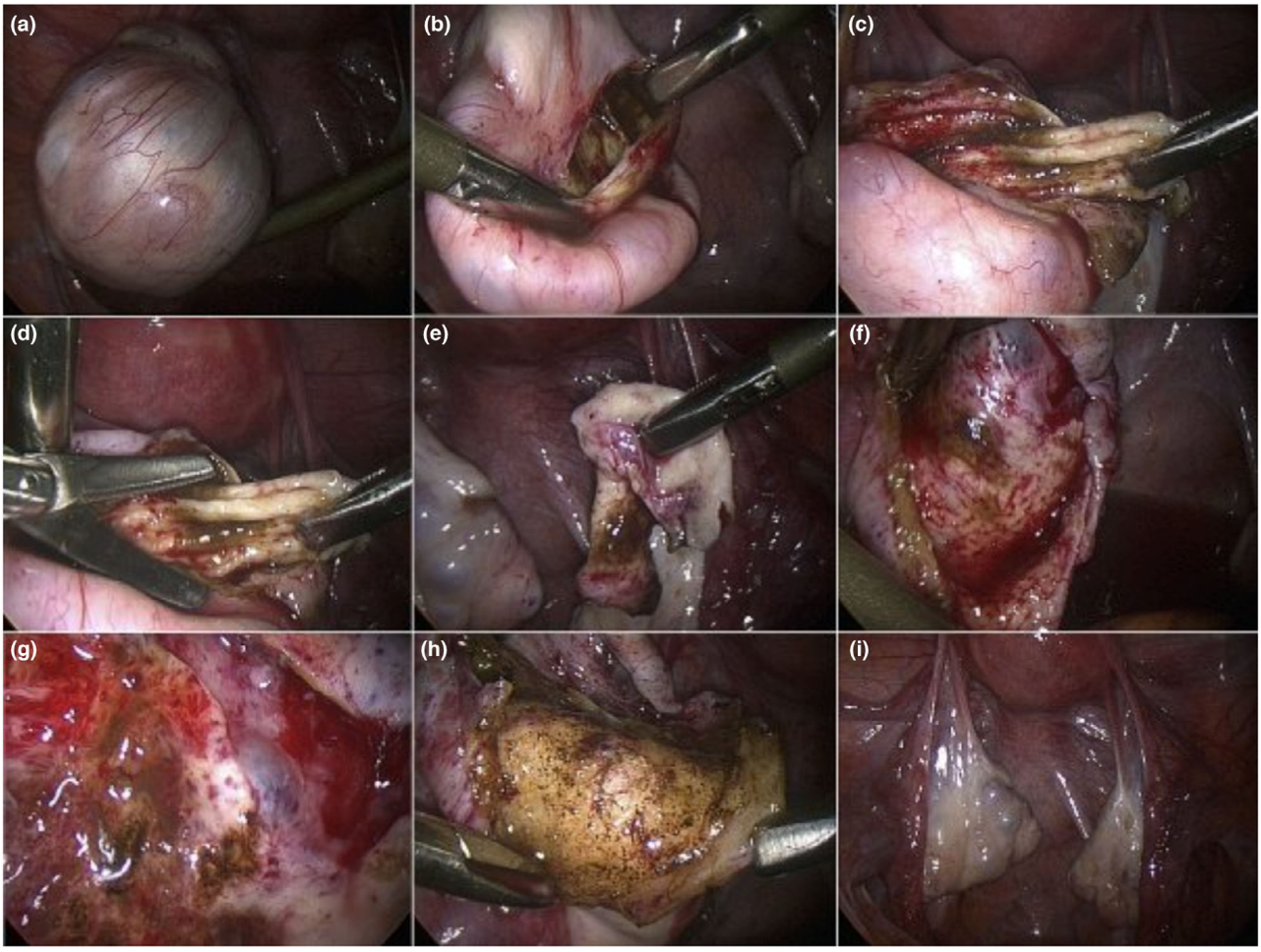

Figure 2. Combined technique: laparoscopic view. (a) Ovarian endometriosis or endometrioma. (b) The endometrioma is opened; detection of the plane of cleavage between the endometrioma wall and ovarian cortex. (c) Cystectomy of the endometrioma. (d) Partial cystectomy: section of the endometrioma wall. (e) Resected part of the endometrioma. (f) Residual part of the cyst. (g) Remaining endometrioma wall on the left side; ovarian cortex after cystectomy on the right. (h) Vaporization of the remaining endometrioma wall. (i) Final pelvic view; the ovary does not usually require suturing. Reproduced with permission from Zanetta et al.[60]

in a cohort of 20 patients.[67] While the study did not evaluate reproductive outcomes, it demonstrated a significantly higher AFC in patients undergoing the three-step procedure. Additionally, in a separate study, the three-step approach yielded comparable findings for AMH levels at both 6 and 12 months post-operatively.[68] However, this approach necessitates two separate surgical procedures and a treatment duration exceeding 12 weeks, which may present a significant burden for patients of reproductive age owing to the resultant delay in conception attempts.

Another technique, proposed by the same group, that prevents the need for repeated surgery is the combined excisional (cystectomy) and ablative technique.[69] In this procedure, a partial cystectomy is initially performed. When the excision causes bleeding or the cleavage plane is not clear or reaches the hilus, the rest of the cyst wall is vaporised using CO_2 laser. The results indicate high spontaneous pregnancy rates (40% after 8 months) and low recurrence rates (<2%) but have not been corroborated in RCTs yet.

Figure 2 demonstrates the combined technique.

Oophorectomy

Planned oophorectomy may be chosen in certain situations, such as upon atypical appearances on imaging, recurrent endometriomas or when there are no further fertility plans. An advantage of this approach is to eliminate recurrence in the same ovary, especially if there has been recurrence on one or more occasion and possible reduction in the risk of ovarian cancer.[7,70] There are no data on its impact on pain improvement compared with conservative surgery. Ovarian endometrioma surgery carries a small risk of unplanned oophorectomy. The ESHRE guidelines emphasise the importance of preoperative counselling for women with endometriosis, including the risk of a decrease in ovarian reserve and, particularly for patients with a history of ovarian surgery, possible loss of the entire ovary.[7]

Haemostatic techniques

Following cystectomy, haemostasis can be achieved using diathermy, suturing or a haemostatic matrix. A recent systematic review of 10 RCTs reported that non-thermal techniques were more preservative to ovarian function. More specifically, it highlighted that laparoscopic suturing was superior to bipolar coagulation when comparing both AMH and AFC, with the use of haemostatic matrix ranking second.[71] In the vast majority of included studies, the type of suture was a continuous stitch using predominantly a monofilament suture with a starting and finishing knot, although in one included RCT with a small number of patients and short follow-up, a barbed monofilament suture was used with no significant changes in post-operative AMH levels compared with normal sutures. The potential for intestinal blockage should be taken into consideration if barbed sutures are used and steps should be taken to prevent that risk.[72]

The use of oxidised regenerated cellulose (Surgicel®) has also been shown in an RCT to reduce the risk of recurrence when used after a cystectomy or drainage of an endometrioma.[73] Table 3 summarises the main benefits and drawbacks of the possible haemostatic methods.

Table 3. Haemostatic techniques after surgical treatment of endometrioma

Technique	Potential risks and limits	Advantages
Bipolar coagulation	Detrimental to ovarian reserve, particularly in large ovarian beds.	Precise haemostatic effect. Technically easy and cost effective.
Ultrasound scalpel coagulation	Similarly detrimental to ovarian reserve as bipolar coagulation. Equipment cost.	Precise haemostatic effect. Technically easy.
Haemostatic gelatin-thrombin matrix sealant (Floseal®)	Allergic reaction in patients sensitive to bovine materials. Gelatin-based products can potentiate bacterial growth. Equipment cost.	Preserves ovarian function better than electrocautery.
Oxidized regenerated cellulose (Surgicel®)	Small risk of foreign-body granulomatous formation	Preserves ovarian function better than electrocautery. Might prevent cyst recurrence.
Polysaccharide haemostatic powder (perclot®)	Contraindicated in patients sensitive to starch or starch-derived materials. Effective only in mild bleeding. No evidence from RCTs	Preserves ovarian function better than electrocautery.
Suturing with a normal suture (usually monofilament)	Technically challenging, requires additional dexterity and training. Prolongs operating time.	Most preservative to ovarian function compared with all other techniques. Cost-effective
Suturing with a barbed monofilament suture	Documented risk of intestinal blockage. Scanty data regarding effect on ovarian function. Equipment cost.	Technically easier, negates the need of tying knots. Reduced operating time compared with normal suturing.

Conclusion

Pre-operative counselling and patient selection are equally as important as choosing the most appropriate surgical technique for patients with ovarian endometriosis. When a patient opts to proceed with surgical management, the surgeon needs to find the right balance between excessive surgery (resulting in removal of normal ovarian cortex) and incomplete surgery (resulting in early recurrence). To achieve that, endometriosis surgeons need to be trained in recognising areas of excessive fibrosis and exercise caution around the hilus. In addition, awareness of how to use different types of diathermy with minimal thermal spread and haemostatic agents that are less detrimental to healthy ovarian tissue is important.

Improving fertility in women with endometriomas is one of the top identified priorities of research in endometriosis,[74] and a well-designed RCT is overdue to help answer whether surgical treatment is an efficient strategy for managing women with subfertility, with the caveat that a balanced approach is followed which considers all medical evidence alongside individual patient factors and preferences, recognising the potential issues of sole reliance on randomised studies.[75] This will help to reduce the uncertainty in decision making where evidence is currently scarce.

Disclosure of interests

ALG is a Trainee Representative on the Editorial Board of TOG; he was excluded from editorial decisions and had no involvement in the decision to publish. CB declares to be a member of the independent data monitoring committee for a clinical study by ObsEva and receiving research grants from Bayer, Roche Diagnostics, MDNA Life Sciences and Volition. ES received honoraria for the provision of training to healthcare professionals from Hologic, Arthrex, Intuitive and Karl Storz. AL declares no conflicts of interest.

Author contributions

ALG instigated the article, reviewed the literature, wrote the manuscript and revised the final draft after critical appraisal by CMB and ES. AL instigated the article, reviewed the literature and wrote the manuscript. CMB and ES oversaw the development of the manuscript and made editorial amendments. All authors approved the final version.

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