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ORIGINAL ARTICLE

Effect of embryo cryopreservation before surgery on clinical outcomes in IVF patients with endometrioma

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Abstract

Purpose: This study evaluated whether embryo cryopreservation before surgery (ECBS) improves clinical outcomes in in vitro fertilization (IVF) patients with endometrioma.

Methods: This retrospective study included patients aged 28–42 years with endometrioma who underwent oocyte retrieval at our hospital from 2019 to 2022. Seventeen patients who underwent ECBS and 43 patients who underwent embryo transfer (ET) without surgery were included. Patient characteristics, reproductive outcomes, and obstetric outcomes were compared between the groups.

Results: Maximum cyst size was significantly larger in the ECBS group than in the control group. The abortion rate per pregnancy was significantly lower (0% vs. 35.5%) in the ECBS group than in the control group. The ongoing pregnancy rate per case was significantly higher in the ECBS group than in the control group (88.2% vs. 58.1%), while the time to ongoing pregnancy was similar. Among patients in the ECBS group who experienced live births, 84.6% became pregnant following three or fewer ET attempts. Multivariate analysis revealed that ECBS was the only factor associated with ongoing pregnancy. The rates of perinatal complications are comparable between the groups.

Conclusions: ECBS is an effective method to improve reproductive outcomes in IVF patients with endometrioma without prolonging the time to pregnancy.

KEYWORDS
embryo cryopreservation before surgery, embryo transfer, endometrioma, endometriosis, in vitro fertilization

1 | INTRODUCTION

Endometriosis affects up to 10% of women of reproductive age and can significantly impact fertility.[1] Among women with endometriosis, 17%–44% present with ovarian endometrioma.[2,3] A considerable proportion of these patients eventually require treatment with assisted reproductive technologies (ARTs), including in vitro fertilization (IVF) and embryo transfer (ET). While surgical intervention may enhance the likelihood of natural conception in patients with stage I/II endometriosis, as classified by

the revised American Society for Reproductive Medicine (rASRM) system,[4] surgical excisions of ovarian endometrioma have a negative impact on ovarian reserve.[5,6] A prospective randomized cohort study shows that ovarian surgery resulted in longer stimulation, higher FSH requirement, and lower oocyte number, but fertilization, pregnancy, and implantation rates do not differ between the control and the surgery group.[7] Therefore, surgery for ovarian endometriomas is not routinely recommended before ART treatment due to the lack of evidence to improve reproductive outcomes.[8] Nevertheless, surgical management can be beneficial in specific cases to enable pathological diagnosis and reduce the risk of pregnancy-related complications. However, the ability of endometrioma excision to improve pregnancy outcomes before ET cycles remains unclear.

To address the potential reduction in ovarian reserve associated with surgery, a therapeutic approach involving preoperative cryopreservation of in vitro fertilized embryos, defined here as embryo cryopreservation before surgery (ECBS), may be considered. Our previous research demonstrated the efficacy of ECBS in women of advanced reproductive age with uterine fibroids.[9] According to European Society of Human Reproduction and Embryology (ESHRE) guidelines for fertility preservation and for endometriosis, benign disease including ovarian endometriosis can be an indication for fertility preservation.[10,11] Despite its theoretical benefits, there are currently no data on the efficacy of ECBS in IVF patients with endometriomas. In this study, we retrospectively evaluated whether ECBS improves reproductive outcomes in IVF patients with ovarian endometriomas compared with conventional IVF treatment.

2 | MATERIALS AND METHODS

2.1 | Study design

This was a retrospective cohort study. IVF patients with endometrioma who underwent oocyte pick-up (OPU) between January 2019 and December 2022 were included in this study. A total of 114 patients with endometriosis were retrospectively reviewed. Eight patients who underwent surgery before OPU and 20 patients who did not have endometrioma were excluded. The remaining 86 patients were divided into two groups: the control group ($n = 58$), which comprised patients who underwent ET without surgery after OPU, and the ECBS group ($n = 28$), which comprised patients who underwent surgery for endometrioma between OPU and the first ET cycle. The exclusion criteria were as follows: age < 25 or ≥ 43 years (control: $n = 3$), history of adenomyomectomy (control: $n = 5$), previous history of IVF (control: $n = 3$, ECBS: $n = 3$), myomectomy during ECBS (ECBS: $n = 8$), and ET not performed (control: $n = 4$). After exclusion of ineligible patients, the control group ($n = 43$) and the ECBS group ($n = 17$) were analyzed. In the ECBS group, OPU was repeatedly performed until at least three frozen embryos were collected, and all patients underwent cystectomy. After OPU cycles, patients were informed of the pros and cons of surgery, and patients decided whether ECBS was performed or not based on ovarian reserve and the size of cysts.

This study was approved by the Institutional Review Board of the University of Tokyo (registration number: 3128-(7)). All patients were informed that their clinical data may be used for research and scientific publications, and each patient provided signed informed consent prior to IVF treatment.

2.2 | IVF-ET protocols

All patients received controlled ovarian stimulation with clomiphene citrate (Clomid, Fuji Pharma Co.), letrozole (Femara, Novartis), or a daily injection of human menopausal gonadotropin (HMG TEIZO or Gonapure, ASKA Pharmaceutical Co.) or recombinant follicle-stimulating hormone (FSH; follitropin alfa (Gonal-F, Merck Biopharma) or follitropin delta (Rekovelle, Fering)), with downregulation by a gonadotropin-releasing hormone (GnRH) agonist (Nasanyl, Pfizer Japan), a GnRH antagonist (Ganirest, MSD K.K.), or dydrogesterone (Duphaston, Viatris). When the diameter of the leading follicle reached 18–20 mm, ovulation was induced with a single injection of human chorionic gonadotropin (10 000 IU; HCG Mochida, Mochida Pharmaceutical Co.) or a GnRH agonist (Supurecur, Clinigen). Oocytes were retrieved 34 h after the trigger. All embryos were cryopreserved on day 3 or 5. ET was performed during natural or hormone replacement therapy cycles. Oral antibiotics were administered for 4 days starting from 1 day before ET or OPU, and vaginal antibiotics were administered for at least 2 days before ET or OPU to prevent infection after procedures.

2.3 | Outcome measures

Patients' medical records were retrospectively reviewed until December 2024. The following data were assessed: age at OPU, body mass index (BMI), gravidity, parity, previous operative history, cyst size, AMH level (ng/mL), basal FSH level (mIU/mL), presence of adenomyosis and uterine fibroids, number of OPU cycles, number of oocytes retrieved, fertilization rate (number of fertilized eggs/number of oocytes retrieved), freezing rate (number of frozen embryos/number of fertilized eggs), number of frozen embryos, number of ET cycles, rASRM score, and endometriosis infertility index (EFI) score.[12] The clinical pregnancy and ongoing pregnancy rates per ET and per case were calculated. Clinical pregnancy was confirmed by the presence of a gestational sac in the uterine cavity by transvaginal ultrasonography. An ongoing pregnancy was defined as a pregnancy that continued beyond 12 weeks of gestation. The primary outcome was the ongoing pregnancy rate per case. The secondary outcomes were the clinical pregnancy rate per case, clinical pregnancy rate per ET, ongoing pregnancy rate per ET, abortion rate per pregnancy, and time to pregnancy. Obstetric outcomes, including gestational age, the rate of cesarean section, birth weight, and the rates of perinatal complications, were compared between the control and ECBS groups.

2.4 | Statistical analysis

Statistical analysis was performed with GraphPad Prism 10 (GraphPad Software Inc.) and JMP Pro 14 software (SAS Institute Inc.). Shapiro–Wilk test was used for the test of normal distribution. Data were compared using Fisher's exact test and the unpaired t-test for normally distributed data, and the Mann Whitney test for non-normally distributed data. Nominal logistic regression analysis was used for the estimation of predictive factors associated with ongoing pregnancy. A p-value of <0.05 was considered statistically significant, and all reported p-values are two-sided.

TABLE 1 Comparison of patients' characteristics between control and ECBS group.

Patient characteristic	Control $n=43$	ECBS $n=17$	p-value
Age (year)	36.7±3.3	35.2±4.6	0.2328
BMI (kg/m^2)	21.8±3.2	23.1±2.9	0.2892
Nulligravid	76.7% (32/43)	58.8% (10/17)	0.1970
Nulliparous	86.0%(37/43)	88.2%(15/17)	>0.9999
History of cystectomy	23.2% (10/43)	29.4% (5/17)	0.7426
History of myomectomy	7.0% (3/43)	5.9% (1/17)	>0.9999
Maximum cyst size (mm)	33.6±14.8	59.4±19.5	<0.0001
Bilateral	46.5% (20/43)	35.3% (6/17)	0.5656
AMH (ng/mL)	2.0±1.7	2.4±1.6	0.2319
Basal FSH (mIU/mL)	8.9±3.1	9.3±1.3	0.4277
Adenomyosis	37.2% (16/43)	17.6% (4/17)	0.3752
Uterine fibroid	18.6% (8/43)	23.5% (5/17)	0.4879

Note: Data are shown as mean±SD.

Abbreviations: AMH, anti-Müllerian hormone; BMI, body mass index; FSH, follicle-stimulating hormone.

3 | RESULTS

3.1 | Comparison of patients' characteristics between the control and ECBS groups

Patients' characteristics are shown in Table 1. Age, BMI, gravidity, parity, operative history of the ovaries, the basal FSH level, the AMH level, and the rates of uterine fibroids and adenomyosis did not significantly differ between the groups. The maximum cyst size was significantly larger in the ECBS group than in the control group (59.4±19.5 mm vs. 33.6±14.8 mm, $p<0.0001$). The rate of bilateral cysts did not significantly differ between the groups.

3.2 | ECBS strategy for endometrioma

In the ECBS group, the mean numbers of OPU cycles and frozen embryos before surgery were 2.2±1.8 and 7.6±4.2, respectively. Of the 17 patients in the ECBS group, 16 (94.1%) underwent cystectomy with laparoscopy. The mean rASRM and EFI scores were 67.6±39.6 and 4.6±2.4, respectively.

3.3 | Comparison of reproductive outcomes between the control and ECBS groups

Reproductive outcomes are shown in Table 2. The numbers of OPU and ET cycles, the number of oocytes retrieved, fertilization rate, and freezing rate were comparable between the groups. While the clinical pregnancy rate per ET was comparable between the groups, the

TABLE 2 Reproductive outcomes between control and ECBS group.

	Control $n=43$	ECBS $n=17$	p-value
The number of OPU cycles	2.2±1.8	2.2±1.7	0.8114
Number of oocytes retrieved	5.8±3.6	7.7±3.9	0.0735
Fertilization rate	68.0±18.0%	76.0±8.2%	0.0861
Freezing rate	73.0±22.6%	78.8±18.1%	0.4301
The number of ET cycles	2.7±1.6	2.7±1.6	0.4602
Clinical pregnancy/ET	30.0% (31/103)	34.8% (16/48)	0.7089
Ongoing pregnancy/ET	19.4% (20/103)	34.8% (16/48)	0.0683
Abortion/pregnancy	35.5% (11/31)	0% (0/16)	0.0085
Clinical pregnancy/case	58.1% (25/43)	88.2% (15/17)	0.0340
Ongoing pregnancy/case	44.1% (19/43)	88.2% (15/17)	0.0031
Time to ongoing pregnancy (month)	9.7±8.3	10.8±5.8	0.1947

Note: Data are shown as mean±SD.

Abbreviations: ET, embryo transfer; OPU, oocyte pick-up.

ongoing pregnancy rate per ET was higher in the ECBS group than in the control group (34.8% vs. 19.4%, $p=0.0683$). The abortion rate per pregnancy was significantly lower in the ECBS group than in the control group (0% vs. 35.5%, $p=0.0085$). The ongoing pregnancy rate per case was significantly higher in the ECBS group than in the control group (88.2% vs. 58.1%, $p=0.0340$). In the ECBS group, two patients spontaneously became pregnant after using all frozen embryos, while no patients spontaneously became pregnant in the control group. Additionally, 84.6% (11/13) of patients in the ECBS group experienced live births following three or fewer ET attempts. The cumulative pregnancy rate is illustrated in Figure 1. The cumulative pregnancy rate in the ECBS group increased at 6 months after the first OPU. The time to ongoing pregnancy did not significantly differ between the control and ECBS groups (9.7±8.3 months vs. 10.8±5.8 months).

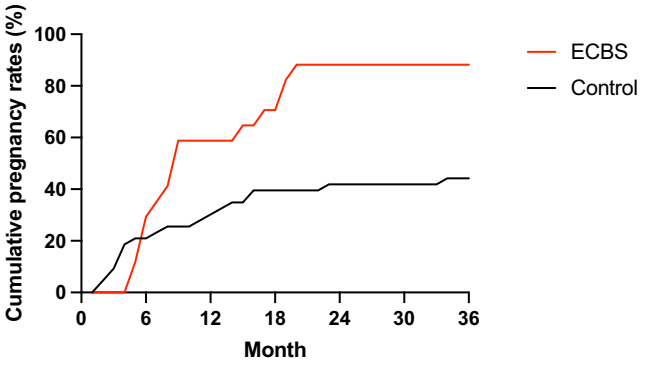

FIGURE 1 Cumulative ongoing pregnancy rates. Cumulative ongoing pregnancy rates are plotted from the time of OPU.

We compared characteristics between cases with ongoing pregnancy and cases without ongoing pregnancy (Table 3). Patients with ongoing pregnancy were significantly younger than those without ongoing pregnancy (35.6±4.0 vs. 37.8±3.3, $p=0.0222$). The total number of frozen embryos and the rate of ECBS were significantly higher in cases with ongoing pregnancy than those without ongoing pregnancy. We performed nominal logistic regression analysis to determine the factors associated with the successful of ongoing pregnancy. It revealed that ECBS was the only contributing factor associated with ongoing pregnancy (odds ratio 10.8 [95% confidence interval 1.18–99.2], $p=0.0354$).

TABLE 3 Comparison of characteristics between patients with ongoing pregnancy and those without ongoing pregnancy.

	Ongoing pregnancy (−)	Ongoing pregnancy (+)	Univariate analysis	Multivariate analysis	
	(*n*=26)	(*n*=34)	*p*-value	Odds ratio (95% CI)	*p*-value
Age (year)	37.8±3.3	35.6±4.0	0.0222	0.13 (0.0071–1.96)	0.1379
Maximum cyst size (mm)	36.3±18.9	44.7±20.0	0.1153	0.66 (0.013–22.4)	0.8272
Bilateral	38.5% (10/26)	(16/34)	0.6025	2.16 (0.54–8.65)	0.2779
History of cystectomy	26.9% (7/26)	(7/34)	0.759	0.65 (0.14–2.92)	0.5694
AMH (ng/mL)	1.7±1.3	2.3±1.9	0.1867	3.23 (0.11–159.0)	0.5155
Basal FSH (mIU/mL)	9.4±3.0	8.9±2.8	0.5113	0.31 (0.0081–10.2)	0.5109
Adenomyosis	34.6% (9/26)	29.4% (10/34)	0.7814	2.05 (0.45–9.16)	0.3466
Uterine Fibroid	23.1% (6/26)	17.6% (6/34)	0.7471	0.59 (0.10–3.30)	0.5464
Total number of embryos frozen	4.3±3.7	6.0±3.7	0.0224	4.39 (0.11–207.7)	0.4182
ECBS	7.7% (2/26)	44.1% (15/34)	0.0031	10.8 (1.18–99.2)	0.0354

Note: Data are shown as mean±SD.

Abbreviations: AMH, anti-Müllerian hormone; BMI, body mass index; CI, confidence interval; ECBS, embryo cryopreservation before surgery; FSH, follicle-stimulating hormone.

3.4 | Comparison of obstetric outcomes between the control and ECBS groups

Obstetric outcomes of patients who gave birth were compared between the groups. Among patients who gave birth, one patient in the control group and three patients in the ECBS group delivered twice. Among the 37 deliveries, two deliveries in the control group without information during pregnancy and delivery were excluded; thus, 35 deliveries were analyzed. Gestational age, type of delivery, and birth weight did not significantly differ between the groups (Table 4). Regarding perinatal complications, the rate of placental previa tended to be higher in the control group than in the ECBS group, but the difference was not significant (16.7% vs. 0%, $p=0.2286$). No case suffered an infection or rupture of a cyst during pregnancy in either group.

4 | DISCUSSION

In this study, we examined the efficacy of ECBS, a combination therapy of ART treatment and cystectomy, for women with endometrioma. The ongoing pregnancy rates per case were significantly higher in the ECBS group than in the control group. The cumulative pregnancy rate in the ECBS group increased 6 months after the first OPU, while the time to ongoing pregnancy did not significantly differ between the groups. Most patients in the ECBS group conceived following three or fewer ET attempts. ECBS was the only contributing factor associated with ongoing pregnancy. The abortion rate per pregnancy was significantly lower in the ECBS group than in the control group, while obstetric outcomes did not significantly differ between the groups.

Endometriosis affects fertility through several mechanisms. Pelvic adhesions disrupt pelvic anatomy and tubal function, and the chronic inflammatory environment can interfere with ovulation, sperm function, fertilization, and endometrial receptivity.[13,14] Ovarian endometrioma can decrease ovarian reserve and oocyte developmental competence.[14] Patients with severe endometriosis (stage III/IV) and endometrioma have significantly reduced pregnancy rates upon IVF treatment.[15,16] However, surgery for endometrioma negatively affects ovarian reserve because it reduces the antral follicle count[17] and it also increases the risk of cycle cancellation due to a poor response and oocyte retrieval failure.[18] However, ECBS appears to mitigate the negative impact of surgery on ovarian reserve. A concern is that endometrioma may hinder access to ovarian follicles. However, in our study, a sufficient number of embryos (7.6 ± 4.2) were frozen with a mean of 2.2 OPU cycles, and there were no complications, such as rupture or infection of cysts, during OPU cycles. The effect of endometriosis on embryo quality remains debated.[14] A recent meta-analysis suggested that endometriosis does not affect embryo morphology.[19] A recent retrospective analysis using time-lapse technology observed altered relative kinetics in embryos from patients with endometriosis, indicative of poorer embryo quality.[20] Laparoscopic excision of endometrioma does not improve oocyte developmental competence in comparison with oocytes from the contralateral healthy ovary.[21] Considering the potential impact of surgery on ovarian reserve, oocyte retrieval before surgery is a reasonable approach if ovarian follicles can be accessed.

According to the ESHRE Endometriosis Guideline 2022, surgery for endometrioma prior to ART treatment should not be routinely recommended to improve live birth rates.[10] Systematic reviews and meta-analyses have not demonstrated a significant beneficial effect of surgery for endometrioma on live birth rates.[17,22] However, the efficacy of ECBS for endometrioma remains unclear. One study reported clinical outcomes following surgery–ART hybrid therapy for endometrioma and uterine fibroids.[23] In that study, the total pregnancy rate per ET was 33.7% (29/86) and the live birth rate was 16.2%. However, only 16 of 36 cases had ovarian endometrioma; therefore, the specific efficacy for ovarian endometrioma was not clearly demonstrated. In our study, the ongoing pregnancy rates per case were significantly higher in the ECBS group than in the control group. The peritoneal environment of endometriosis may affect implantation and early embryo development.[14] The levels of proinflammatory cytokines and growth factors are elevated in follicular fluid of endometriosis patients.[24,25] Follicular fluid released into the peritoneal cavity during ovulation affects the peritoneal microenvironment. Animal models have shown that peritoneal fluid from

TABLE 4 Obstetrics outcomes between control and ECBS group.

	Control	ECBS	
	$n=18$	$n=17$	p-value
Gestational days	274 ± 12	274 ± 9	0.4754
% of CS	44.4% (8/18)	47.0% (8/17)	>0.9999
Birth weight (g)	3146 ± 515	3233 ± 419	0.2922
Complications			
Preeclampsia	11.1% (2/18)	11.8% (2/17)	>0.9999
GDM	0% (0/18)	5.9% (1/17)	0.4857
Placenta previa	16.7% (3/18)	0% (0/17)	0.2286
Placenta accreta spectrum disorder	11.1% (2/18)	5.9% (1/17)	>0.9999

Note: Data are shown as mean ± SD.

Abbreviations: CS, cesarean section; GDM, gestational diabetes mellitus.

women with endometriosis reduces implantation rates.[26,27] A systematic review and meta-analysis indicate that the miscarriage rate is elevated in endometriosis patients.[13,28] In our study, the abortion rate per pregnancy was significantly lower in the ECBS group than in the control group. Surgery for ovarian endometrioma may improve the peritoneal microenvironment, thereby increasing ongoing pregnancy rates and reducing abortion rates.

Endometriosis increases the risk of pregnancy and delivery complications, including preeclampsia, preterm delivery, and postpartum hemorrhage.[13] Placenta previa and placenta accreta spectrum disorders are strongly associated with endometriosis. Women undergoing ART treatment are more likely to experience these conditions than those who do not undergo ART treatment.[29] It is unknown whether surgical treatment for endometriosis improves perinatal complications. A literature review of three studies did not provide sufficient evidence due to heterogeneous designs.[30] A recent case–control study showed that among patients with stage III/IV endometriosis, the incidence of placenta previa was significantly reduced in those who underwent complete surgery. In our study, obstetric outcomes did not significantly differ between the groups, but the incidence of placenta previa tended to be lower in the ECBS group than in the control group. Although it is rare, surgery for endometrioma can prevent ovarian cyst problems during pregnancy. In our cases, no ruptures or infections of ovarian cysts were observed. Further studies are needed to evaluate the effect of surgery on perinatal outcomes.

One concern with ECBS is that the perioperative contraceptive period may delay the time to pregnancy. The cumulative pregnancy rate was lower in the ECBS group than in the control group during the first 5 months following the first OPU, but was higher after 6 months. Most patients in the ECBS group conceived following three or fewer ET cycles, suggesting that cryopreserving three or more embryos before surgery is optimal to minimize the interval between OPU and surgery. Another concern is that surgery for endometrioma may diminish ovarian function in patients whose ovarian reserve is already reduced. It is essential to discuss the advantages and disadvantages of ECBS and provide personalized treatment for each patient.

This study has several limitations. First, it was a single-center, retrospective control study. The small sample size may have influenced the results. The detailed evaluation of reproductive and obstetric outcomes contributed to the limited sample size. Second, the control group did not undergo laparoscopy, meaning endometrioma was confirmed using imaging alone. Laparoscopy and pathological diagnosis remain the most reliable methods to assess the severity of endometriosis. The use of imaging alone may have underestimated the impact of endometriosis in the control group. Third, some patient characteristics, such as maximum cyst size, differed between the groups. Larger cysts were more likely to be surgically removed, introducing potential selection bias. Despite the possibility that endometriosis was more severe in the ECBS group, reproductive outcomes were better in this group than in the control group. Besides, multivariate analysis revealed that there were no differences in patients' backgrounds between cases with ongoing pregnancy and those without ongoing pregnancy except for ECBS. Future randomized cohort studies are needed, comparing reproductive outcomes between patients who underwent ovarian cystectomy and conventional IVF patients or those who underwent laparoscopic observation, to eliminate confounding factors.

In conclusion, ECBS is an effective method to improve reproductive outcomes in IVF patients with endometrioma without prolonging the time to pregnancy. It appears advantageous to cryopreserve three or more embryos before surgery to optimize outcomes. Future prospective cohort studies with larger sample sizes are needed to identify patients who would benefit most from ECBS for endometriosis.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Datasets can be requested from the corresponding author.

ETHICS STATEMENT

Institutional Review Board of the University of Tokyo (registration number: 3128-(7)).

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REFERENCES

1. Zondervan KT, Becker CM, Missmer SA. Endometriosis. N Engl J Med. 2020;382:1244–56.
2. Redwine DB. Ovarian endometriosis: a marker for more extensive pelvic and intestinal disease. Fertil Steril. 1999;72:310–5.
3. Jenkins S, Olive DL, Haney AF. Endometriosis: pathogenetic implications of the anatomic distribution. Obstet Gynecol. 1986;67:335–8.
4. Hodgson RM, Lee HL, Wang R, Mol BW, Johnson N. Interventions for endometriosis-related infertility: a systematic review and network meta-analysis. Fertil Steril. 2020;113:374–382.e2.
5. Somigliana E, Berlanda N, Benaglia L, Viganò P, Vercellini P, Fedele L. Surgical excision of endometriomas and ovarian reserve: a systematic review on serum antimüllerian hormone level modifications. Fertil Steril. 2012;98:1531–8.
6. Raffi F, Metwally M, Amer S. The impact of excision of ovarian endometrioma on ovarian reserve: a systematic review and meta-analysis. J Clin Endocrinol Metab. 2012;97:3146–54.

7. Demirol A, Guven S, Baykal C, Gurgan T. Effect of endometrioma cystectomy on IVF outcome: a prospective randomized study. Reprod Biomed Online. 2006;12:639–43.
8. Hamdan M, Dunselman G, Li TC, Cheong Y. The impact of endometrioma on IVF/ICSI outcomes: a systematic review and meta-analysis. Hum Reprod Update. 2015;21:809–25.
9. Takahashi N, Harada M, Tanabe R, Takayanagi A, Izumi G, Oi N, et al. Factors associated with successful pregnancy in women of late reproductive age with uterine fibroids who undergo embryo cryopreservation before surgery. J Obstet Gynaecol Res. 2018;44:1956–62.
10. Becker CM, Bokor A, Heikinheimo O, Horne A, Jansen F, Kiesel L, et al. ESHRE guideline: endometriosis. Hum Reprod Open. 2022;2022:hoac009.
11. ESHRE Guideline Group on Female Fertility Preservation, Anderson RA, Amant F, Braat D, D'Angelo A, de Sousa C, Demeestere I, et al. ESHRE guideline: female fertility preservation. Hum Reprod Open. 2020;2020:hoaa052.
12. Adamson GD, Pasta DJ. Endometriosis fertility index: the new, validated endometriosis staging system. Fertil Steril. 2010;94:1609–15.
13. Vercellini P, Viganò P, Bandini V, Buggio L, Berlanda N, Somigliana E. Association of endometriosis and adenomyosis with pregnancy and infertility. Fertil Steril. 2023;119:727–40.
14. Bonavina G, Taylor HS. Endometriosis-associated infertility: from pathophysiology to tailored treatment. Front Endocrinol. 2022;13:1020827.
15. Opøien HK, Fedorcsak P, Omland AK, Abyholm T, Bjercke S, Ertzeid G, et al. In vitro fertilization is a successful treatment in endometriosis-associated infertility. Fertil Steril. 2012;97:912–8.
16. Harb HM, Gallos ID, Chu J, Harb M, Coomarasamy A. The effect of endometriosis on in vitro fertilisation outcome: a systematic review and meta-analysis. BJOG. 2013;120:1308–20.
17. Hamdan M, Omar SZ, Dunselman G, Cheong Y. Influence of endometriosis on assisted reproductive technology outcomes: a systematic review and meta-analysis. Obstet Gynecol. 2015;125:79–88.
18. Şükür YE, Özmen B, Yakıştıran B, Atabekoğlu CS, Berker B, Aytaç R, et al. Endometrioma surgery is associated with increased risk of subsequent assisted reproductive technology cycle cancellation; a retrospective cohort study. J Obstet Gynaecol. 2021;41:259–62.
19. Dongye H, Ji X, Ma X, Song J, Yan L. The impact of endometriosis on embryo quality in in-vitro fertilization/intracytoplasmic sperm injection: a systematic review and meta-analysis. Front Med. 2021;8:669342.
20. Freis A, Dietrich JE, Binder M, Holschbach V, Strowitzki T, Germeyer A. Relative morphokinetics assessed by time-lapse imaging are altered in embryos from patients with endometriosis. Reprod Sci. 2018;25:1279–85.
21. Harada M, Takahashi N, Hirata T, Koga K, Fujii T, Osuga Y. Laparoscopic excision of ovarian endometrioma does not exert a qualitative effect on ovarian function: insights from in vitro fertilization and single embryo transfer cycles. J Assist Reprod Genet. 2015;32:685–9.
22. Nickkho-Amiry M, Savant R, Majumder K, Edi-O'sagie E, Akhtar M. The effect of surgical management of endometrioma on the IVF/ICSI outcomes when compared with no treatment? A systematic review and meta-analysis. Arch Gynecol Obstet. 2018;297:1043–57.
23. Kuroda K, Ikemoto Y, Ochiai A, Ozaki R, Matsumura Y, Nojiri S, et al. Combination treatment of preoperative embryo cryopreservation and endoscopic surgery (surgery-ART hybrid therapy) in infertile women with diminished ovarian reserve and uterine myomas or ovarian endometriomas. J Minim Invasive Gynecol. 2019;26:1369–75.
24. Singh AK, Dutta M, Chattopadhyay R, Chakravarty B, Chaudhury K. Intrafollicular interleukin-8, interleukin-12, and adrenomedullin are the promising prognostic markers of oocyte and embryo quality in women with endometriosis. J Assist Reprod Genet. 2016;33:1363–72.
25. Choi YS, Cho S, Seo SK, Park JH, Kim SH, Lee BS. Alteration in the intrafollicular thiol-redox system in infertile women with endometriosis. J Reprod Fertil. 2015;149:155–62.
26. Steinleitner A, Lambert H, Kazensky C, Danks P. Peritoneal fluid from endometriosis patients affects reproductive outcome in an in vivo model. Fertil Steril. 1990;53:926–9.
27. Illera MJ, Juan L, Stewart CL, Cullinan E, Ruman J, Lessey BA. Effect of peritoneal fluid from women with endometriosis on implantation in the mouse model. Fertil Steril. 2000;74:41–8.
28. Horton J, Sterrenburg M, Lane S, Maheshwari A, Li TC, Cheong Y. Reproductive, obstetric, and perinatal outcomes of women with adenomyosis and endometriosis: a systematic review and meta-analysis. Hum Reprod Update. 2019;25:592–632.
29. Matsuzaki S, Ueda Y, Nagase Y, Matsuzaki S, Kakuda M, Kakuda S, et al. Placenta accreta spectrum disorder complicated with endometriosis: systematic review and meta-analysis. Biomedicine. 2022;10:390.
30. Mooney SS, Ross V, Stern C, Rogers PAW, Healey M. Obstetric outcome after surgical treatment of endometriosis: a review of the literature. Front Reprod Health. 2021;3:750750.

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