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Original Research

The Impact of Laparoscopic Versus Open Conservative Surgery for Adenomyosis on Subsequent *In Vitro* Fertilization Outcomes: A Retrospective Cohort Study

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Abstract

Background: With the widespread adoption of fertility-preserving conservative surgery for adenomyosis in clinical practice, the impact of different surgical approaches on subsequent reproductive outcomes has become a key clinical concern. This study aimed to investigate the impact of laparoscopic versus open conservative surgery for adenomyosis on subsequent *in vitro* fertilization (IVF) outcomes. Adenomyosis is a recognized cause of female infertility; yet, the optimal surgical approach for patients seeking to preserve fertility remains debated, and comparative data on their effect on subsequent IVF outcomes are limited. **Methods:** This single-center retrospective cohort study included 162 infertile women with adenomyosis who underwent primary conservative surgery (98 laparoscopic, 64 open) between January 2018 and December 2023. Diagnosis was confirmed by imaging and histopathology. Strict exclusion criteria were applied to minimize confounding. The primary outcome was live birth rate following postoperative IVF. Multivariate logistic regression was used to evaluate the independent effects of surgical approach and intraoperative factors on live birth. **Results:** Baseline characteristics were comparable between groups, except for a higher proportion of diffuse adenomyosis in the open surgery group (65.6% vs. 28.6%, $p < 0.001$). As expected, open surgery was associated with longer intraoperative blood loss (103 [55–140] vs. 61 [30–80] mL, $p < 0.001$), and larger resected lesion volume (40 [22–58] vs. 23 [12–32] cm^3, $p < 0.001$). However, postoperative IVF parameters and pregnancy outcomes showed no significant differences. Clinical pregnancy rates (laparoscopic vs. open: 48.0% vs. 50.0%, $p = 0.795$) and live birth rates (36.7% vs. 37.5%, $p = 0.917$) were similar. Multivariate analysis confirmed that surgical approach was not an independent predictor of live birth (adjusted odds ratio [OR] = 1.05, 95% confidence interval [CI]: 0.54–2.04, $p = 0.882$). Intraoperative blood loss and resection volume were likewise not significantly associated with live birth. **Conclusions:** Within the limitations of this retrospective design, the choice between laparoscopic and open conservative surgery in infertile patients with adenomyosis was not found to significantly affect subsequent IVF live birth outcomes. Surgical decisions may therefore be guided by individual lesion characteristics and surgeon expertise, as the approach alone does not appear to compromise fertility potential based on the available evidence.

Keywords: adenomyosis; infertility; conservative surgical treatment; pregnancy outcome

1. Introduction

Adenomyosis is a common benign gynecological condition affecting approximately 20% of women of reproductive age. Its main clinical manifestations include abnormal uterine bleeding, pelvic pain, and infertility [1,2]. The pathological hallmark of adenomyosis is the invasion of endometrial glands and stroma into the myometrium, leading to uterine enlargement, disruption of myometrial architecture, and functional impairment of the endometrio-myometrial junctional zone, which may subsequently interfere with embryo implantation and early pregnancy maintenance [3,4]. In recent years, advances in imaging techniques and growing emphasis on fertility preservation have led to the widespread adoption of conservative surgical treatment for adenomyosis in clinical practice [5,6].

The primary surgical approaches include laparoscopic surgery and open abdominal surgery. The choice between these procedures typically depends on the extent and location of the lesions, symptom severity, and the patient's fertility goals [7,8]. For diffuse adenomyosis or extensive lesions involving the posterior uterine wall, open abdominal surgery is often preferred to achieve more complete lesion resection. In contrast, laparoscopic surgery is generally favored for focal adenomyosis or cases with mild pelvic adhesions, due to its minimally invasive nature and faster recovery [9,10]. Nevertheless, the two surgical approaches may differ in terms of intraoperative blood loss, extent of lesion resection, and postoperative uterine healing, all of which could potentially impact outcomes following assisted reproductive technology (ART) [11,12].

Current studies have investigated natural conception and *in vitro* fertilization (IVF) outcomes in infertile patients with adenomyosis following conservative surgery, suggesting that postoperative reductions in uterine volume and symptom improvement may be associated with higher fertility success rates [13,14]. However, comparative studies specifically examining the impact of different surgical approaches, laparoscopic versus open surgery, on subsequent IVF outcomes remain relatively limited [15,16]. Furthermore, the existing literature lacks a systematic evaluation of the relationship between intraoperative variables, such as blood loss and resection volume, and live birth outcomes following IVF.

Therefore, this study retrospectively analyzed clinical data from infertile patients with adenomyosis who underwent conservative surgical treatment at our center. The objectives were to compare intraoperative indicators and postoperative IVF outcomes between laparoscopic and open abdominal surgery, to explore whether the surgical approach and associated intraoperative factors influence live birth rate, and to provide evidence to inform clinical decision-making regarding the choice of surgical technique.

2. Methods

2.1 Study Design and Participant Selection

This was a single-center retrospective cohort study. Patients with infertility and adenomyosis who attended the reproductive center of Sir Run Run Shaw Hospital between January 2018 and December 2023 were systematically screened for eligibility. All participants underwent primary conservative surgical treatment (laparoscopic or open surgery). The diagnosis of adenomyosis was confirmed by preoperative transvaginal ultrasonography and/or pelvic magnetic resonance imaging and subsequently verified by postoperative histopathological examination. Infertility was defined according to international standards as the failure to achieve a clinical pregnancy after at least 12 months of regular unprotected intercourse.

2.2 Inclusion and Exclusion Criteria

The inclusion criteria were as follows: (1) age between 20 and 45 years; (2) meeting the diagnostic criteria for both adenomyosis and infertility as previously described; (3) undergoing first-time conservative surgical treatment for adenomyosis; and (4) receiving postoperative IVF treatment at our center.

To minimize the interference of confounding factors on the outcomes, strict exclusion criteria were applied: (1) male factor as the primary cause of infertility; (2) presence of other gynecological conditions significantly affecting fertility, such as uncontrolled ovulatory disorders, polycystic ovary syndrome (PCOS), or other uterine anomalies (e.g., uncorrected uterine septum); (3) comorbid major systemic diseases (e.g., malignant neoplasm, autoimmune diseases); (4) history of prior uterine surgery (e.g., myomectomy, prior adenomyosis resection); and (5) incomplete surgical records or postoperative follow-up data. Of 215 patients initially screened, 162 were included after applying the exclusion criteria. Patient allocation at each stage is detailed in Fig. 1.

2.3 Clinical Definitions and Outcome Measures

Based on histopathological findings, adenomyosis was classified as diffuse or focal. The diffuse type was defined as widespread infiltration of endometrial glands and stroma throughout the myometrium, whereas the focal type (adenomyoma) presented as relatively well-circumscribed nodular lesions within the myometrium. Primary infertility was defined as never having achieved a clinical pregnancy, and secondary infertility referred to the inability to conceive following at least one previous clinical pregnancy.

The primary outcome measure of this study was the live birth rate following postoperative IVF cycles. Secondary outcome measures included clinical pregnancy rate (confirmed by the presence of an intrauterine gestational sac and fetal cardiac activity on ultrasound), biochemical pregnancy rate (elevated serum human chorionic gonadotropin (hCG) not meeting clinical pregnancy criteria), miscarriage rate, and incidence of postoperative complications. All pregnancy outcomes were calculated per patient who underwent at least one embryo transfer cycle after surgery. Accordingly, the denominators for live birth rate and clinical pregnancy rate were based on the number of patients who received at least one embryo transfer following postoperative IVF. In this cohort, all 162 included patients underwent at least one embryo transfer cycle after surgery.

2.4 Surgical Intervention and Data Collection

Surgical indication was determined based on a comprehensive assessment encompassing: (1) clinical symptoms (e.g., severe dysmenorrhea or heavy menstrual bleeding poorly controlled by medication); (2) imaging findings suggestive of significant uterine enlargement (uterine volume equivalent to $\geq$8 weeks of gestation) or lesions potentially compromising the uterine cavity environment; and (3) coexisting symptomatic pelvic endometriosis.

The surgical approach was determined by senior attending physicians based on lesion characteristics, in accordance with routine clinical practice rather than a randomized allocation. Open abdominal surgery was preferred for patients with diffuse lesions, lesions predominantly involving the posterior uterine wall, or those for whom preoperative assessment indicated severe pelvic adhesions, with the aim of achieving more complete lesion resection and reliable uterine closure. Laparoscopic surgery was prioritized for patients with focal disease or mild adhesions. This non-randomized selection process introduced potential selection bias, which is addressed in the statistical analysis and discussion.

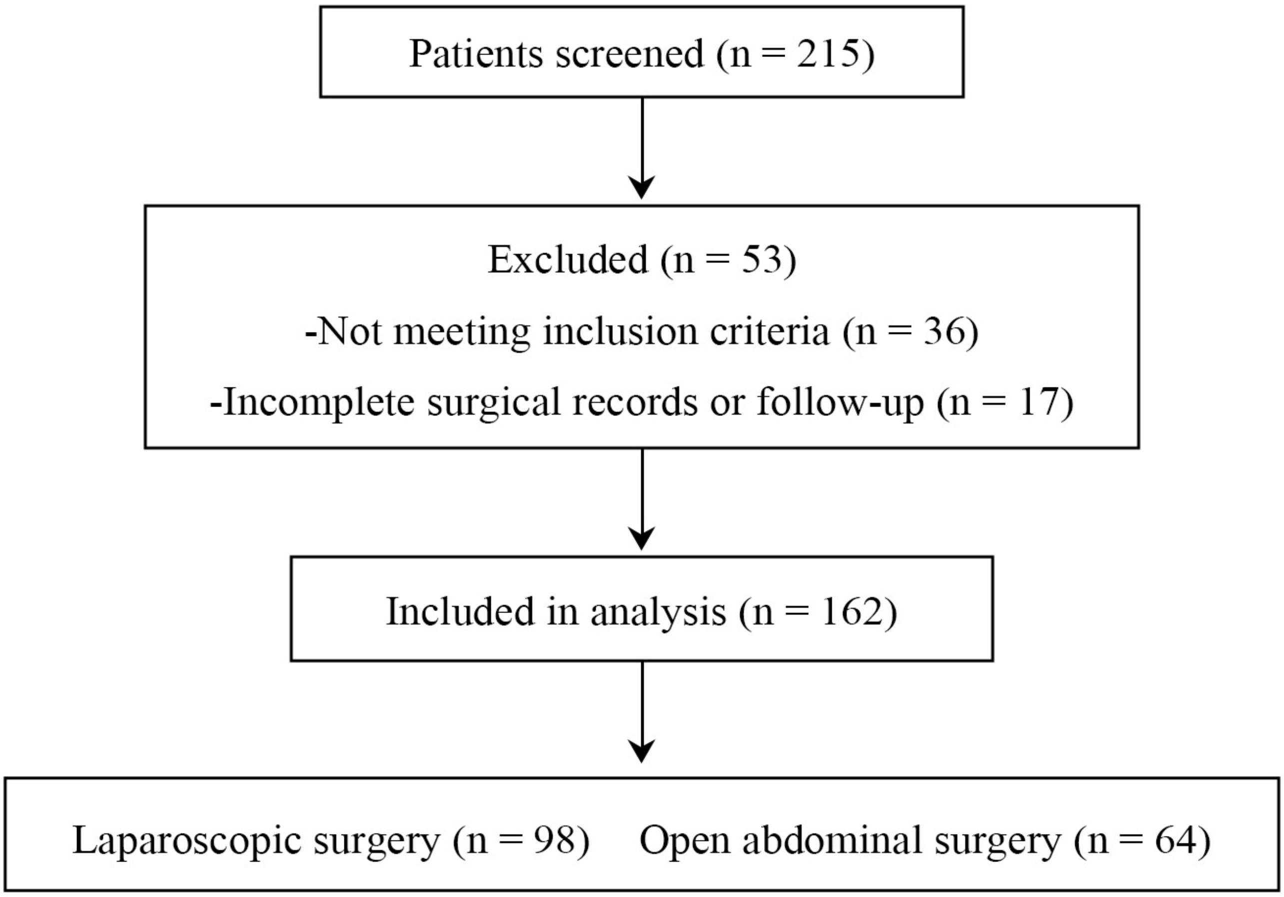

Fig. 1. Flowchart of patient selection.

All surgeries were performed or supervised by experienced senior surgeons. Standardized techniques were used for both approaches: following lesion excision, the uterine wall was reconstructed in multiple layers using delayed absorbable sutures (e.g., Vicryl) to ensure adequate myometrial closure. For focal adenomyosis, complete excision of the adenomyoma with preservation of surrounding healthy myometrium was attempted. For diffuse adenomyosis, a cytoreductive approach was used to reduce adenomyotic volume while maintaining uterine integrity. With the exception of the access method and suturing instrumentation, the surgical technique did not differ substantially between the laparoscopic and open approaches.

Intraoperative data, including operative time and estimated blood loss, were recorded. The volume of resected lesions was calculated using the prolate ellipsoid formula (volume = 0.52 × length × width × height), based on measurements obtained from preoperative imaging or postoperative specimens. When endometriosis was identified intraoperatively, it was staged according to the revised American Fertility Society (rAFS) classification and treated accordingly. Concurrent tubal pathologies (e.g., hydrosalpinx) and intrauterine pathologies (e.g., polyps detected during hysteroscopy) were also addressed at the time of surgery. Postoperatively, patients were advised to defer pregnancy for 3 to 12 months based on the depth of myometrial involvement and extent of resection. The timing of the first postoperative IVF cycle was recorded.

Postoperative IVF protocol: Following the recommended waiting period, patients underwent controlled ovarian stimulation using a gonadotropin-releasing hormone (GnRH) antagonist or agonist protocol, selected according to individual ovarian reserve and prior response at the discretion of the treating reproductive endocrinologist. Embryo transfer was performed as either fresh or frozen-thawed, with frozen-thawed embryo transfer being preferred when endometrial preparation was required or to reduce the risk of ovarian hyperstimulation syndrome. The number of embryos transferred followed national guidelines based on patient age and embryo quality. Live birth was defined as delivery of a live infant beyond 24 weeks of gestation. Data on IVF cycles, including the number of cycles per patient, were collected. For patients who underwent multiple cycles, only the first postoperative cycle was included to avoid within-patient clustering effects.

2.5 Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 27.0 (IBM Corp, Armonk, NY, USA). Normality of continuous variables was assessed using the

Shapiro-Wilk test. Normally distributed variables are presented as mean ± standard deviation (SD) and were compared using the independent samples t-test. Non-normally distributed variables are presented as median (interquartile range, IQR) and were compared using the Mann-Whitney U test. In the current manuscript, some continuous variables that deviated from normality are presented as median (IQR) in the tables, and the text descriptions have been aligned accordingly. Categorical variables are described by frequency (percentage) and were compared using the chi-square test or Fisher's exact test.

To assess the independent effect of the surgical approach on live birth outcomes, multivariate logistic regression analysis was performed. Variables with a p-value <0.2 in univariate analysis, including age, surgical approach, intraoperative blood loss, resected lesion volume, adenomyosis type, coexisting endometriosis, duration of infertility, and prior ART attempts, were considered for inclusion. The final multivariable model included the following variables based on observed data: age, preoperative anti-Müllerian hormone (AMH), adenomyosis type (diffuse vs. focal), duration of infertility, and prior ART attempts. Surgical approach (open vs. laparoscopic), intraoperative blood loss, and resected lesion volume were also retained in the model to test their independent effects. A stepwise forward selection method (likelihood ratio) was used for variable selection. Adjusted odds ratios (ORs) and their 95% confidence intervals (CIs) were calculated. All tests were two-sided, and a p-value < 0.05 was considered statistically significant. Given the non-randomized assignment and baseline imbalance in adenomyosis type, we adjusted for these factors in the regression model. However, residual confounding due to unmeasured variables (e.g., lesion severity, surgical difficulty) cannot be entirely excluded and is acknowledged as a limitation.

3. Results

The patient selection process is detailed in Fig. 1, which shows that 215 patients were initially screened, 53 were excluded, and 162 met the eligibility criteria. After applying strict inclusion and exclusion criteria, a total of 162 patients were ultimately included in the analysis, comprising 98 in the laparoscopic surgery group and 64 in the open abdominal surgery group.

Comparison of baseline characteristics between the two groups (Table 1) showed no statistically significant differences in age, body mass index (BMI), distribution of infertility type, basal FSH level, or preoperative AMH level ($p > 0.05$), indicating comparability between the two groups in terms of basic fertility characteristics. Additional baseline variables, including duration of infertility and number of prior ART attempts, were also comparable between groups. However, the proportion of diffuse adenomyosis was significantly higher in the open abdominal surgery group compared with the laparoscopic surgery group (65.6% vs. 28.6%, $p < 0.001$), indicating greater disease severity in the open surgery group.

Analysis of surgical outcomes (Table 2) showed that the open abdominal surgery group presented significantly greater operative time, intraoperative blood loss, and resected lesion volume compared with the laparoscopic surgery group ($p < 0.001$). Specifically, the median (IQR) operative time was 146 (115–178) minutes for the open abdominal surgery group, compared with 125 (100–150) minutes in the laparoscopic surgery group. Median (IQR) blood loss was 103 (55–140) mL in the open abdominal surgery group versus 61 (30–80) mL in the laparoscopic surgery group. The median (IQR) resected lesion volume was 40 (22–58) cm^3 in the open abdominal surgery group and 23 (12–32) cm^3 in the laparoscopic surgery group.

Comparison of postoperative IVF treatment parameters (Table 3) revealed no significant differences between the two groups in the duration of gonadotropin (Gn) use, total Gn dosage, number of oocytes retrieved, fertilization rate, or high-quality embryo rate ($p > 0.05$). Endometrial thickness at the time of embryo transfer was also comparable (median (IQR): 10.1 (8.5–11.7) mm vs. 9.9 (8.0–11.8) mm, $p = 0.593$). The median interval from surgery to the first postoperative IVF cycle was 6.0 months (IQR: 4.0–8.0 months) in the laparoscopic group and 6.0 months (IQR: 4.0-9.0 months) in the open abdominal surgery group ($p = 0.612$). Postoperative cancer antigen 125 (CA-125) levels at 6 months were compared using the Mann-Whitney U test. The median (IQR) values were 58 (32–80) U/mL in the laparoscopic surgery group and 96 (60–130) U/mL in the open abdominal surgery group, with a p-value of 0.105. Although the numerical values differed, the difference did not reach statistical significance, likely due to high interpatient variability and limited sample size.

Analysis of pregnancy outcomes (Table 4) showed no significant differences between the two groups regarding clinical pregnancy rate, miscarriage rate, or live birth rate. The clinical pregnancy rate was 48.0% (47/98) in the laparoscopic surgery group and 50.0% (32/64) in the open abdominal surgery group ($p = 0.795$). Regarding live birth rate, it was 36.7% (36/98) in the laparoscopic surgery group and 37.5% (24/64) in the open abdominal surgery group ($p = 0.917$). The denominator for these rates was the total number of patients in each group. All pregnancy outcomes were calculated per patient who underwent at least one embryo transfer cycle after surgery. In this cohort, all 162 included patients underwent at least one embryo transfer; therefore, the denominator for each group is the full group size. Biochemical pregnancy rates and ectopic pregnancy rates were also similar between the groups.

Multivariate logistic regression analysis, adjusted for potential confounding factors, showed that the surgical approach was not an independent factor affecting live birth rate (OR = 1.05, 95% CI: 0.54–2.04, $p = 0.882$) (Table 5). Age was a significant factor influencing live birth rate (OR = 0.91, 95% CI: 0.84–0.99, $p = 0.032$), whereas preopera-

Table 1. Baseline characteristics of study patients.

Parameter	Laparoscopic surgery (n = 98)	Open abdominal surgery (n = 64)	*p*-value
Age (years), median (IQR)	34 (31–37)	35 (32–38)	0.423
BMI (kg/m^2), median (IQR)	22.0 (20.0–24.5)	22.0 (19.5–24.5)	0.521
Duration of infertility (months), median (IQR)	24 (12–36)	24 (12–36)	0.682
Prior ART attempts, median (IQR)	1 (0–2)	1 (0–2)	0.754
Infertility type			0.690
Primary infertility, n (%)	52 (53.1)	36 (56.3)	
Secondary infertility, n (%)	46 (46.9)	28 (43.8)	
Basal FSH (IU/L), median (IQR)	7.6 (6.1–9.5)	8.0 (6.3–9.8)	0.445
Preoperative AMH (ng/mL), median (IQR)	2.6 (1.2–4.1)	2.5 (1.1–4.3)	0.872
Adenomyosis type, n (%)			<0.001
Diffuse	28 (28.6)	42 (65.6)	
Focal	70 (71.4)	22 (34.4)	
Coexisting endometriosis, n (%)	53 (54.1)	38 (59.4)	0.507

Note: Continuous variables were tested for normality; non-normally distributed variables are presented as median (IQR). The *p*-values for infertility type and coexisting endometriosis were calculated using the chi-square test. BMI, body mass index; IQR, interquartile range; FSH, follicle-stimulating hormone; AMH, anti-Müllerian hormone; ART, assisted reproductive technology.

Table 2. Comparison of intraoperative parameters between surgical groups.

Surgical parameter	Laparoscopic surgery (n = 98)	Open abdominal surgery (n = 64)	*p*-value
Operative time (min), median (IQR)	125 (100–150)	146 (115–178)	<0.001
Blood loss (mL), median (IQR)	61 (30–80)	103 (55–140)	<0.001
Resected lesion volume (cm^3), median (IQR)	23 (12–32)	40 (22–58)	<0.001
Postoperative hospital stay (days), median (IQR)	3 (2–4)	5 (4–6)	<0.001

Note: All continuous variables were non-normally distributed and are therefore presented as median (IQR). Group comparisons were performed using the Mann-Whitney U test.

Table 3. Postoperative IVF treatment parameters.

IVF parameter	Laparoscopic surgery (n = 98)	Open abdominal surgery (n = 64)	*p*-value
Gn duration (days), median (IQR)	10 (9–12)	10 (9–12)	0.387
Total Gn dose (IU), median (IQR)	2250 (1600–2900)	2380 (1700–3100)	0.356
Oocytes retrieved (n), median (IQR)	8 (4–12)	8 (3–12)	0.645
Fertilization rate (%), median (IQR)	75 (62–88)	74 (60–88)	0.598
High-quality embryo rate (%), median (IQR)	53 (35–70)	51 (33–68)	0.658
Endometrial thickness on transfer day (mm), median (IQR)	10.1 (8.5–11.7)	9.9 (8.0–11.8)	0.593
Postoperative CA-125 (U/mL), median (IQR)	58 (32–80)	96 (60–130)	0.105
Surgery-to-IVF interval (months), median (IQR)	6.0 (4.0–8.0)	6.0 (4.0–9.0)	0.612

Note: *p*-values were calculated using the Mann-Whitney U test for continuous variables. IVF, *in vitro* fertilization; Gn, gonadotropin.

Table 4. Comparison of pregnancy outcomes.

Pregnancy outcome	Laparoscopic surgery (n = 98)	Open abdominal surgery (n = 64)	*p*-value
Clinical pregnancy, n (%)	47 (48.0)	32 (50.0)	0.795
Biochemical pregnancy, n (%)	9 (9.2)	6 (9.4)	0.964
Miscarriage, n (%)	11 (11.2)	8 (12.5)	0.799
Ectopic pregnancy, n (%)	2 (2.0)	1 (1.6)	1.000
Live birth, n (%)	36 (36.7)	24 (37.5)	0.917

Note: Denominator is the number of patients who underwent at least one embryo transfer cycle after surgery (laparoscopic surgery group, n = 98; open abdominal surgery group, n = 64). All outcomes are reported per patient.

Table 5. Multivariate logistic regression analysis of factors affecting live birth rate.

Variable	Adjusted OR	95% CI	*p*-value
Surgical approach (open vs. laparoscopic)	1.05	0.54–2.04	0.882
Age (years)	0.91	0.84–0.99	0.032
Preoperative AMH (ng/mL)	1.14	0.99–1.32	0.072
Intraoperative blood loss (mL)	1.00	0.99–1.01	0.665
Resected lesion volume (cm^3)	1.01	0.99–1.02	0.423
Adenomyosis type (diffuse vs. focal)	0.87	0.45–1.68	0.674
Duration of infertility (months)	1.01	0.98–1.04	0.520
Prior ART attempts (n)	0.92	0.70–1.21	0.550

Note: Variables were selected using forward stepwise (likelihood ratio) method. The model was adjusted for age, AMH, adenomyosis type, duration of infertility, and prior ART attempts. OR, odds ratio; CI, confidence interval; AMH, anti-Müllerian hormone; ART, assisted reproductive technology.

Table 6. Comparison of postoperative and pregnancy complications.

Complication	Laparoscopic surgery (n = 98)	Open abdominal surgery (n = 64)	*p*-value
Postoperative complications			
Postoperative fever, n (%)	2 (2.0)	6 (9.4)	0.038
Wound infection, n (%)	1 (1.0)	2 (3.1)	0.560
Pregnancy complications			
Hypertensive disorders, n (%)	4 (4.1)	3 (4.7)	1.000
Gestational diabetes mellitus, n (%)	8 (8.2)	7 (10.9)	0.581
Placenta previa, n (%)	3 (3.1)	2 (3.1)	1.000
Preterm birth, n (%)	5 (5.1)	4 (6.3)	1.000
Uterine rupture, n (%)	0 (0)	0 (0)	-

Note: Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. The denominator for all pregnancy-related complications was the total number of patients in each surgical group (laparoscopic surgery group, n = 98; open abdominal surgery group, n = 64).

tive AMH levels showed marginal significance (OR = 1.14, 95% CI: 0.99–1.32, $p = 0.072$). Intraoperative blood loss (OR = 1.00, 95% CI: 0.99–1.01, $p = 0.665$) and resected lesion volume (OR = 1.01, 95% CI: 0.99–1.02, $p = 0.423$) were not significantly correlated with live birth rate. The regression model also included duration of infertility and prior ART attempts, neither of which reached statistical significance.

Regarding postoperative complications, the incidence of postoperative fever was significantly higher in the open abdominal surgery group compared with the laparoscopic surgery group (9.4% vs. 2.0%, $p = 0.038$) (Table 6). For pregnancy complications, there were no significant differences in the rates of hypertensive disorders of pregnancy, gestational diabetes mellitus, placenta previa, or preterm birth between the two groups. Furthermore, no uterine rupture occurred in any of the live birth cases in this study.

We further performed a subgroup analysis based on adenomyosis type. Among patients with diffuse adenomyosis, there was no statistically significant difference in live birth rate between the laparoscopic and open abdominal surgery groups (35.7% vs. 38.1%, $p = 0.832$). Similarly, among patients with focal adenomyosis, the live birth rates were comparable between the two groups (37.1% vs. 36.4%, $p = 0.954$).

4. Discussion

This retrospective study analyzed the clinical data from 162 patients with infertility and adenomyosis who underwent conservative surgery, either laparoscopic or open abdominal surgery. Although the open abdominal surgery group presented with a higher proportion of diffuse lesions, resulting in greater intraoperative blood loss, larger resected lesion volume, and longer operative time (all $p < 0.001$), reflecting the greater surgical complexity in this group, multivariate analysis showed that the surgical approach itself was not an independent predictor of live birth rate following postoperative IVF. Furthermore, intraoperative blood loss and the extent of resection were not significantly correlated with live birth outcomes. Within the limitations of the retrospective design and the substantial baseline imbalance in disease severity between groups (diffuse adenomyosis: 65.6% in the open group vs. 28.6% in the laparoscopic group), these findings suggest that the choice of surgical approach may not be a key determinant of subsequent IVF success in this cohort. These results provide preliminary evidence supporting individualized surgical planning in clinical practice; however, causal inference remains limited by the non-randomized design.

Previous studies on the impact of adenomyosis surgery on fertility have largely focused on comparisons between surgical versus non-surgical treatment, or on the general evaluation of surgical efficacy [17,18]. However, for infertile patients and clinicians, clear evidence regarding which of the two most common approaches, laparoscopic or open abdominal surgery, better optimizes IVF outcomes has been lacking [11]. This study directly compared the two surgical approaches and systematically evaluated surgery-related variables, such as blood loss and lesion resection volume, finding that none of these factors independently affected live birth rate. This aligns with earlier studies [6,19], which reported that various surgical techniques could improve fertility outcomes; however, our study further clarifies, through multivariate analysis, that the surgical approach itself is not the key determinant of outcome.

These findings should not be interpreted as evidence of equivalence between laparoscopic and open abdominal surgery. Rather, they indicate that, in this cohort and after adjustment for measured confounders, no statistically significant difference in live birth rates was observed. The absence of a significant difference may reflect the limited sample size, the marked imbalance in disease severity between groups, and potential residual confounding. Therefore, caution is warranted when generalizing these results to all patients with adenomyosis, and the choice of surgical approach should continue to be guided by lesion characteristics and surgical expertise rather than assumed equivalence.

Our findings may address concerns raised in the literature regarding the potential impact of laparoscopic suturing quality on uterine healing and subsequent pregnancy outcomes [19]. Although open surgery may theoretically offer more robust suturing conditions, the laparoscopic group in this study demonstrated comparable live birth rates and pregnancy safety, with no cases of uterine rupture [20]. This suggests that, in the hands of experienced surgeons, laparoscopic multilayer closure using delayed absorbable sutures can achieve adequate uterine wall reconstruction, and postoperative healing appears sufficient to withstand the physiological demands of pregnancy [21]. Therefore, for patients with focal lesions or with diffuse lesions suitable for laparoscopic surgery, opting for the minimally invasive approach does not compromise fertility outcomes based on the current data.

Postoperative CA-125 levels at 6 months, analyzed by the Mann-Whitney U test, showed no statistically significant difference between groups (median [IQR]: 58 [32–80] vs. 96 [60–130] U/mL, $p = 0.105$). The higher CA-125 levels in the open group may reflect more extensive or diffuse disease, consistent with the baseline characteristics; however, the lack of statistical significance, likely due to high inter-individual variability and limited sample size, underscores the difficulty in isolating the effect of surgical approach from underlying disease severity.

The principal clinical implication of this study is that, for infertile patients with adenomyosis requiring surgery, the choice of surgical approach should be guided primarily by lesion-specific characteristics, such as extent, location, relationship to surrounding tissues [22], surgeon proficiency with each technique [17], and individual patient circumstances [23], rather than by potential concerns about adverse effects of a particular approach on IVF outcomes. When the surgeon possesses the requisite technical expertise, the balance of clinical decision-making scale may favor laparoscopic surgery given its minimally invasive nature and associated faster recovery [24].

Limitations

This study has several limitations. First, the retrospective, non-randomized design carries an inherent risk of selection bias. The choice of surgical approach was determined by lesion characteristics and physician judgement rather than random assignment, resulting in a significantly higher proportion of diffuse adenomyosis in the open abdominal surgery group (65.6% vs. 28.6%). Although confounding was addressed through strict inclusion and exclusion criteria and multivariate analysis, residual confounding by unmeasured factors cannot be entirely excluded. This limits any causal interpretation of the observed absence of significant differences in IVF outcomes between the two groups. Second, the statistical reporting of continuous variables in the original manuscript did not consistently reflect the normality assumptions. Some variables that deviated from normality were initially reported as mean ± SD rather than median (IQR). After re-analysis using appropriate non-parametric methods (e.g., Mann-Whitney U test for CA-125), the conclusions remained unchanged; nonetheless, this inconsistency is acknowledged as a limitation. Specifically, postoperative CA-125 levels had median (IQR) values of 58 (32–80) U/mL in the laparoscopic group and 96 (60–130) U/mL in the open abdominal surgery group, and the Mann-Whitney U test yielded a p-value of 0.105. Although the median was higher in the open abdominal surgery group, the difference did not reach statistical significance, likely attributable to large inter-individual variability, as reflected by the wide IQRs, and limited sample size. The possibility of a type II error cannot be ruled out. Third, although the sample size exceeds that of some previous studies, it remains insufficient for detecting rare outcomes such as uterine rupture or for performing more refined subgroup analyses, for example, stratified by lesion location or extent of resection. Fourth, surgical decision-making and operative techniques reflect the experience of a single center, and these conclusions should therefore be generalized with caution. The strengths of this study include a relatively large sample size, systematic data collection, and multivariable adjustment for multiple potential confounding factors.

5. Conclusions

In summary, within the limitations of this retrospective cohort study and the substantial baseline imbalance in disease severity between the two surgical groups, no statistically significant difference in subsequent IVF live birth outcomes was observed between laparoscopic and open abdominal surgery in infertile patients with adenomyosis. Intraoperative blood loss and extent of lesion resection were likewise not significantly associated with the live birth rate. Based on these findings, and acknowledging that residual confounding by indication cannot be excluded despite multivariable adjustment, the surgical approach in clinical practice may be selected according to lesion characteristics and surgeon expertise, as the available evidence does not support an independent effect of the specific approach on IVF live birth outcomes. However, the present findings should not be interpreted as evidence of equivalence between the two surgical approaches. Larger prospective studies with improved control for disease severity and case selection are needed to confirm these observations and to establish more definitive comparative conclusions.

Availability of Data and Materials

All data reported in this paper will also be shared by the corresponding author upon request.

Author Contributions

XLi, JC, LX and DH designed the research study. XLi, JC, LX, YH, JY and YC performed the experiments and acquired the data. XLi and DH analyzed and interpreted the data. WY, XLiu and AZ contributed to data curation and validation, and provided critical input for the interpretation of results. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was approved by Sir Run Run Shaw Hospital IRB on February 21, 2025. (Approval number: 2025 No.1055). Informed consent was obtained from all participants. The study was conducted in accordance with the principles of the Declaration of Helsinki.

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Conflicts of Interest

The authors declare no conflicts of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/CEOG51376.

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