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RESEARCH

Transumbilical laparoendoscopic single-site surgery vs. multiport laparoscopic surgery for benign ovarian cysts: a retrospective cohort study

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Abstract

Background Transumbilical laparoendoscopic single-site surgery (TU-LESS) has gained increasing attention due to the potential to maximize the benefits of laparoscopic surgery. This study aimed to compare outcomes of TU-LESS and multiport laparoscopic surgery (MLS) for the treatment of benign ovarian cysts.

Methods This retrospective cohort study included patients with benign ovarian cysts that were admitted to the Second Hospital of Hebei Medical University between September 2010 and September 2022. Inverse probability of treatment weighting (IPTW) approach weighting were used to compare outcomes of TU-LESS and MLS for benign ovarian cysts. The primary outcome was the rate of cystic content spillage.

Results A total of 528 patients with benign ovarian cysts were included and 236 (44.6%) patients underwent TU-LESS. The risk of cystic content spillage [relative risk (RR) = 4.37, 95% confidence interval (CI): 2.59–7.38), $P < 0.001$] and operation time (β = 4.94, 95% CI: 1.40–8.48, $P = 0.017$) during TU-LESS was significantly higher than that during MLS. While hospital stay (β=-0.10, 95% CI: -0.198 - -0.004, $P = 0.043$) during TU-LESS was significantly shorter. IPTW analyses yielded similar patterns of results. For ovarian cysts < 10 cm, the risk of cystic content spillage, operation time and EBL during TU-LESS was significantly higher than that during MLS (all $P < 0.05$). On the contrast, for ovarian cysts ≥ 10 cm, the risk of cystic content spillage, operation time and EBL during TU-LESS was significantly lower than that during MLS (all $P < 0.05$).

Conclusions TU-LESS had a significantly higher risk of cystic content spillage, longer operation time than MLS. While for ovarian cysts ≥ 10 cm, TU-LESS had a lower risk of cystic content spillage, shorter operation time, and less EBL than MLS. More experienced surgeons are needed to perform TU-LESS in benign ovarian cysts.

Keywords Laparoscopy, Multiport laparoscopic surgery, Laparoendoscopic single-site surgery, Ovarian cyst, Retrospective cohort study

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Background

Benign ovarian cysts constitute one of the most prevalent gynecological tumors affecting both premenopausal and postmenopausal patients, with a lifetime risk estimated at approximately 7% [1]. These abnormalities are predominantly comprised of functional ovarian cysts and benign neoplasms. While most functional cysts resolve on their own and can be monitored, they may occasionally cause symptoms such as pain, menstrual irregularities, and, albeit rarely, intra-abdominal bleeding [2]. However, a substantial proportion of benign ovarian cysts, including ovarian cystadenomas, mature cystic teratomas, and endometriomas, persist over time [3]. Notably, large ovarian cysts (measuring 10 cm or more in diameter) pose an elevated risk of intraoperative rupture due to surgical intervention and an increased likelihood of malignancy, particularly in postmenopausal women [4].

Laparoscopy is widely regarded as the gold standard for treating benign ovarian cysts, owing to its advantages over open surgery, such as reduced postoperative pain, accelerated recovery, shorter hospital stays, and enhanced cosmetic outcomes [5, 6].

Recently, there has been a growing trend toward laparo-endoscopic single-site surgery (LESS), particularly the trans-umbilical approach (TU-LESS), which involves performing surgery through a single incision at the umbilicus [7]. TU-LESS offers several advantages over multiport laparoscopic surgery (MLS), such as enhanced direct visualization for puncture and specimen extraction, and the potential for extracorporeal manipulation of large ovarian cysts [8, 9]. Additionally, prior studies have suggested that TU-LESS may further reduce hospital stays for women with benign ovarian cysts [10]. However, controversy remains as some research has failed to demonstrate the superiority of LESS over MLS in ovarian cyst treatment, citing longer operative times [11–13]. Moreover, there has been a notable increase in the estimated blood loss risk during TU-LESS procedures [14]. Consequently, a consensus on the benefits of TU-LESS for benign ovarian cysts has yet to be established.

The size of ovarian cysts serves as a crucial factor influencing their management, diagnosis, and the choice of surgical approach. In postmenopausal women, unilocular, anechoic cysts measuring less than 5 cm in diameter, accompanied by normal carbohydrate antigen 125 (CA125) levels, can typically be monitored [15]. Conversely, surgical intervention is generally recommended for cysts exceeding 5 cm in diameter and/or exhibiting elevated CA-125 levels [16]. Additionally, larger ovarian cysts are associated with an increased risk of cystic content spillage during surgery [17]. Based on this, we hypothesize that the conflicting results observed in studies comparing TU-LESS and MLS might stem from differences in the size of the cysts being treated. The primary hypothesis guiding our study was that TU-LESS would be advantageous for benign ovarian cysts larger than 10 cm, while MLS would be preferable for cysts smaller than 10 cm. This hypothesis was based on the clinical practice that the multi-port approach offers greater maneuverability and ease of intra-abdominal manipulation for smaller cysts, while the single-site approach, more convenient for external manipulation through the bigger umbilical incision, is better suited for larger cysts.

The primary objective of this study was to conduct a comparative analysis of the outcomes achieved through the utilization of TU-LESS surgery and MLS in the treatment of benign ovarian cysts.

Methods

Study design and patients

This retrospective cohort study included patients with benign ovarian cysts that were admitted to the Department of Gynecology at the Second Hospital of Hebei Medical University between September 2010 and September 2021. The inclusion criteria were: (1) patients aged ≥ 14 years; (2) whose imaging, including ultrasound, computed tomography (CT), or magnetic resonance imaging (MRI) indicated ovarian cystic masses and cystic masses were either hypoechoic or anechoic with a thin wall and no solid area or papillary projections extending into the cavity of the cysts; however, if the imaging indicated a mature teratoma, the cyst could be cystic-solid with bone fragments and hair masses; (3) with normal CA125 (< 35 U/L) and human epididymis protein 4 (HE4) (< 140 pmol/L) levels; (4) who underwent TU-LESS or MLS; and (5) who underwent (unilateral or bilateral) cystectomy, salpingo-oophorectomy, or oophorectomy. The exclusion criteria were: (1) patients who were pregnant; (2) whose ultrasound, CT, MRI or tumor marker results showed malignancy; (3) with any mixed (solid/cystic) component within a cystic ovarian tumor; (4) with elevated tumor markers; (5) with a history of cancer; (6) with a family history of ovarian cancer; (7) with severe pelvic adhesions during intraoperative exploration; (8) who were diagnosed with malignancies or borderline tumors on intraoperative frozen biopsy results; (If the cyst is judged to be benign before surgery, and is accidentally found to be malignant or borderline after surgery); (9) with large retroperitoneal mass; and (10) with incomplete clinical data. This study was approved by the Institutional Research Review Board of the Second Hospital of Hebei Medical University (2019-R087) and adhered to the Declaration of Helsinki. Informed consent was obtained from all participants.

The patients were initially segregated into two distinct groups, namely the TU-LESS group and the MLS group, based on the surgical approach they underwent. Subsequently, during the analysis phase, a decision was made to further stratify these patients according to the size of their ovarian cysts. This stratification entailed dividing the patients into two subgroups: one comprising those with smaller ovarian cysts, defined as having a maximum diameter of less than 10 cm, and the other consisting of patients with larger ovarian cysts, characterized by a maximum diameter of 10 cm or more. This post hoc categorization was undertaken to delve into potential differences in surgical outcomes that might be correlated with the size of the cysts. The choice of 10 cm as the cutoff point was retrospectively determined, as cysts exceeding this size threshold could potentially be manipulated through the umbilicus for extracorporeal interventions, thereby simplifying the surgical procedure and potentially impacting the outcomes.

Data collection

All surgeries were performed under endotracheal general anesthesia and executed by three associate chief physicians, each with extensive experience ranging from 15 to 20 years of service, assisted by two assistants per group. Prior to surgery, patients were positioned in dorsal lithotomy, and urethral catheterization was administered. In the TU-LESS group, the surgical procedure was facilitated through a single access port (HK-FDDC-4Fx, Hangtian Kadi, China), necessitating a small, approximately 10-mm skin incision in the umbilical fold. For cysts smaller than 10 cm in diameter, standard surgical interventions such as cystectomy, salpingo-oophorectomy, or oophorectomy were conducted intra-abdominally, similar to the MLS approach. For cysts 10 cm or larger, the detachable port cap was removed, and gauze was delicately introduced into the peritoneal cavity to envelop the cyst margins, thus preventing intra-abdominal spillage of cyst contents. In the MLS group, surgeries were conducted utilizing four multi-ports (Kangji, China). For cysts measuring less than 10 cm, standard procedures like cystectomy were carried out as usual. For larger cysts (10 cm or more), the trocar needle was repositioned in the iliac fossae trocar (either left or right) to puncture the cystic wall, enabling deflation. Following deflation, the trocar needle was withdrawn, leaving the cannula in place to facilitate aspiration.

The demographic, clinical characteristics, and medical history information were gathered, which encompassed age, prior surgical history, body mass index, the count of preoperative symptoms (including irregular vaginal bleeding, bloating, abdominal pain, nausea, reduced appetite, palpable abdominal mass, and urinary system symptoms), preoperative serum tumor marker levels for CA125 and HE4, as well as the maximum cyst diameter as confirmed by preoperative imaging.

The pre- and post-operative indicators are as follows:

1. The duration of the operation time was measured as the time elapsed from the initial skin incision to the completion of wound closure.
2. Estimated Blood Loss (EBL) was calculated by taking the difference between the total intake and output of flushing fluid, plus the difference in the total weight of the gauze before and after surgery.
3. Pain was assessed using the visual analog scale, with postoperative pain intensity categorized as none (0–2), mild (3–4), moderate (5–6), severe (7–8), and extreme (9–10).
4. Histological types were confirmed through postoperative pathological examination and included serous cystadenoma, mucinous cystadenoma, mature cystic teratoma, endometrioma, and paroophoritic cyst.
5. Cystic spillage was defined as the intraoperative extravasation of cystic contents, as evidenced by electronic medical records and video recordings.
6. The length of postoperative hospital stay was determined by the number of days from admission to discharge.

Outcomes

The primary endpoint of the study focused on assessing the rates of cystic content spillage, while the secondary outcomes encompassed an evaluation of the operation duration, EBL, post-operative pain, and the length of hospital stay.

Statistical analysis

Data were analyzed using R software (version 4.1.3; R Foundation for Statistical Computing). Participants were divided into two groups (TU-LESS or MLS), and their demographic and clinical characteristics of them were described using the mean ± standard deviation (SD) or percentages (%).

The inverse probability weighting calculation step is as follows: ***Setp1: Calculating propensity score (PS)*** The propensity score (PS) is a technique that attempts to estimate the effect of a treatment (surgical method) by accounting for the covariates (baseline factors and surgical related factors) that predict receiving the surgical method. The propensity score is estimated using a logistic regression model in which surgical method (Single Port Laparoscopic Surgery (TU-LESS) and Porous laparoscopic surgery (MLS)) is regressed on the covariates. The estimated PS is the predicted probability of the fitted regression model (1). After estimating the PS, we use inverse probability of treatment weighting (IPW) to control covariates. ***Step 2: Calculating weights*** The weights [1] were calculated as 1/PS for TU-LESS and 1/(1−PS) for MLS. ***Step 3: Balance check*** After weighting, the equilibrium test needs to be carried out, and it is considered to be balance when SMD is less than 0.1. ***Step 4: Causal effect inference*** Based on the weights obtained from step 2, We built a weighted logistic model in which the rupture status is regressed on the surgical method, the size of cyst, the interaction between surgical method and surgical method and covariates. (2) Where group 0 size 0 means group = Single Port Laparoscopic Surgery (TU-LESS) and size ≤ 10 cm, which is used as the reference group during analysis, group 0 size 1 means group = TU-LESS and size > 10 cm, group 1Size 0 means group = Porous laparoscopic surgery (MLS) and size ≤ 10 cm, group 1 size 1 means group = MLS and size > 10 cm.

The table standardized difference compares the difference in means between groups in units of standard deviation (SMD) and can be calculated for both continuous and categorical variables Empirically, SMD < 0.1 was considered balanced in both groups. Risk factors affecting outcomes were analyzed using univariate logistic regression or univariate linear regression analysis. All tests were two-tailed, and *P* values < 0.05 were considered statistically significant.

Results

A total of 645 patients were included, and 84 cases of emergency surgery were excluded, including 34 cases of cyst rupture, 48 cases of cyst torsion, and 2 cases of intra-cystic cysts. In addition, frozen or postoperative pathologically confirmed malignant and borderline 33 cases were also excluded. Finally, 528 patients with benign ovarian cysts were included. Of these, 292 (55.3%) patients underwent MLS, and 236 (44.6%) patients underwent TU-LESS. There were 110 large cysts ≥ 10 cm; 52 and 58 were removed by TU-LESS and MLS, respectively. Meanwhile, there were 418 small cysts < 10 cm; 184 and 234 were removed by TU-LESS and MLS, respectively (Fig. 1). After baseline data were weighted, the SMD of the baseline characteristics of the two TU-LESS and MLS groups was < 0.1, indicating good balance (Table 1 and Fig. 2). Before IPTW, the risk of cystic content spillage (RR = 4.37, 95% CI: 2.59–7.38, *P* < 0.001) and operation time (β = 4.94, 95% CI: 1.40–8.48, *P* = 0.017) during TU-LESS was significantly higher than that during MLS. After IPTW, the risk of cystic content spillage (RR = 3.46, 95% CI: 2.07–5.80, *P* < 0.001) and operation time (Β = 5.58, 95% CI: 2.03–9.13, *P* = 0.002) during TU-LESS was significantly higher than that during MLS (Table 2). Baseline demographic and clinical characteristics of the participants with cyst sizes ≥ 10 cm and < 10 cm were presented in Table 3.

For ovarian cysts ≥ 10 cm, the risk of cystic content spillage (RR = 0.03, 95% CI: 0.00-0.02, *P* < 0.001), operation time (β = -12.48, 95% CI: -20.00 - -4.35, *P* = 0.003) and EBL (β = -15.29, 95% CI: -25.80 - -4.78, *P* = 0.005) during TU-LESS was significantly lower than that during MLS (Table 4), hospital stay (β=-0.02, 95% CI: -0.22- -0.19, *P* = 0.861) during TU-LESS was shorter than that during MLS, although there was no statistical significance. For ovarian cysts < 10 cm, the risk for rates of cystic content spillage (RR = 12.34, 95% CI: 2.31–65.94, *P* = 0.003), operation time (β = 9.55, 95% CI: 5.65–13.4, *P* < 0.001) and EBL (β = 5.05, 95% CI: 1.70–8.40, *P* = 0.003) during TU-LESS was significantly higher than that during MLS (Table 5).

Discussion

This study found that compared to MLS, TU-LESS had a significantly higher risk of cystic content spillage and a longer operation time. However, for benign ovarian cysts ≥ 10 cm, TU-LESS was superior to MLS, exhibiting a lower risk of cystic content spillage, a shorter operation time, and less EBL than MLS. These findings may serve as a valuable reference for surgical selection in patients with benign ovarian cysts.

In our study, we utilized the IPTW approach to balance covariates between groups and approximate causal effects within an observational setting. We opted for this

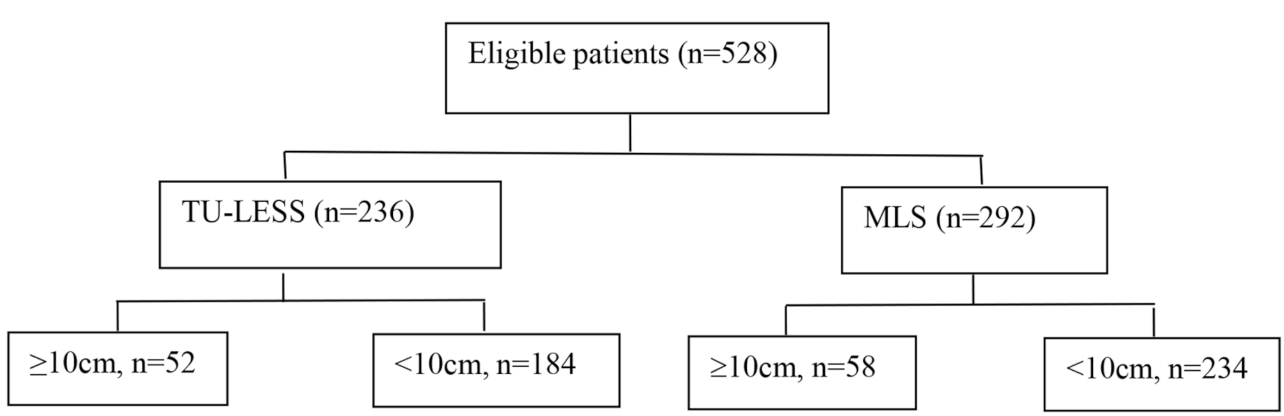

Fig. 1 Study flowchart

Table 1 Baseline demographic and clinical characteristics of the study participants (*n* = 528)

Variables	Full dataset				IPTW			
	TU-LESS (*n* = 236)	MLS (*n* = 292)	*P*	SMD	TU-LESS (*n* = 236)	MLS (*n* = 292)	*P*	SMD
Cyst size (%)								
< 10 cm	184 (78.0)	234 (80.1)	0.615	0.053	407.6 (77.0)	410.7 (77.9)	0.808	0.023
≥ 10 cm	52 (22.0)	58 (19.9)			121.8 (23.0)	116.2 (22.1)		
Preoperative symptom (mean ± SD)	1.91 ± 1.70	1.84 ± 1.57	0.615	0.044	1.93 ± 1.69	1.91 ± 1.64	0.859	0.016
CA125 (mean ± SD)	15.67 ± 5.37	15.55 ± 5.15	0.795	0.023	15.76 ± 5.61	15.67 ± 5.36	0.864	0.016
HE4 (mean ± SD)	49.10 ± 26.75	48.34 ± 23.64	0.730	0.030	49.37 ± 26.68	49.54 ± 24.54	0.944	0.007
Age (mean ± SD)	39.60 ± 16.33	38.75 ± 16.02	0.549	0.052	39.10 ± 16.27	38.94 ± 16.28	0.913	0.010
Unilateral ovary (%)	201 (85.2)	244 (83.6)	0.701	0.044	439.4 ± 83.0	441.7 ± 83.8	0.808	0.023
	35 (14.8)	48 (16.4)			90.0 (17.0)	85.2 (16.2)		
Surgery (%)								
Unilateral salpingo-oophorectomy	29 (12.3)	22 (7.5)	0.333	0.160	51.1 (9.7)	49.9 (9.5)	0.995	0.024
Unilateral ovarian cystectomy	138 (58.5)	180 (61.6)			313.9 (59.3)	318.5 (60.4)		
Bilateral salpingo-oophorectomy	43 (18.2)	55 (18.8)			99.4 (18.8)	96.0 (18.2)		
Bilateral ovarian cystectomy	26 (11.0)	35 (12.0)			64.9 (12.3)	62.5 (11.9)		
Previous surgery history (%)								
Yes	154 (65.3)	196 (67.1)	0.720	0.040	340.0 (64.2)	344.4 (65.4)	0.794	0.024
No	82 (34.7)	96 (32.9)			189.4 (35.8)	182.5 (34.6)		
Pathology (%)								
Serous cystadenoma	99 (41.9)	114 (39.0)	0.331	0.190	220.8 (41.7)	216.1 (41.0)	0.999	0.027
Mucinous cystadenoma	52 (22.0)	63 (21.6)			112.9 (21.3)	112.2 (21.3)		
Mature cystic teratoma	47 (19.9)	56 (19.2)			99.2 (18.7)	100.7 (19.1)		
Endometrioma	21 (8.9)	43 (14.7)			60.4 (11.4)	63.7 (12.1)		
paroophoritic cyst	17 (7.2)	16 (5.5)			36.1 (6.8)	34.2 (6.5)		
BMI, kg/m^2	22.83 ± 4.09	23.86 ± 3.17	0.001	0.281	23.58 ± 4.38	23.50 ± 3.10	0.845	0.020

Note: Data are expressed as median (range), number (%) or mean ± standard deviation (SD)

BMI, Body Mass Index; CA125, carbohydrate antigen 125; HE4, human epididymis protein 4; SMD, standard mean difference

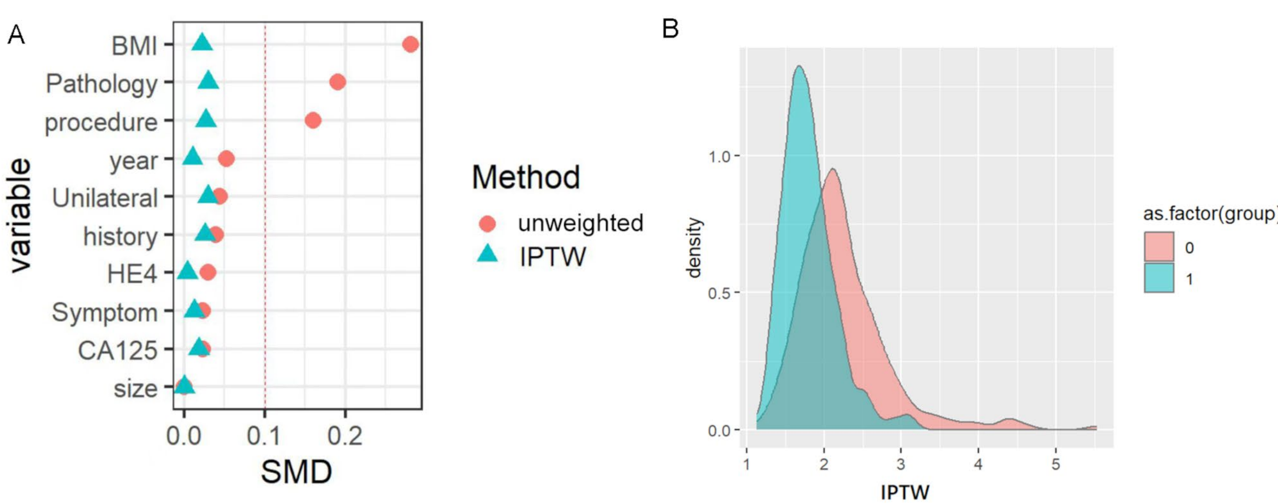

Fig. 2 SMD of the baseline characteristics in unweighted and weighted samples

method over multivariable models to more accurately reflect the average treatment effect in the treated population, which is pivotal to achieving our study objectives. We acknowledge the limitations inherent in IPTW, particularly its reliance on accurate propensity score model specification. If key confounders are omitted or inaccurately modeled, the results may be susceptible to bias. To enhance transparency and understanding, future iterations will elaborate on the variables incorporated into the propensity score model and clarify the application of IPTW weights in our regression analyses. While IPTW is adept at mitigating selection bias, it falls short in adjusting for unmeasured confounders, posing a potential threat to the validity of our findings. Consequently, we

Table 2 Comparison of surgical outcomes before and after IPTW (TU-LESS group vs. MLS group)

Variables	Before IPTW			After IPTW		
	RR	95% CI	*P*	RR	95% CI	*P*
Spillage rate	4.37	2.59–7.38	< 0.001	3.46	2.07–5.80	< 0.001
Operation time	4.94	1.40–8.48	0.017	5.58	2.03–9.13	0.002
EBL	1.41	-2.26–5.08	0.452	-0.09	-3.88–3.71	0.963
Pain	1.65	0.77–3.57	0.201	1.40	0.62–3.19	0.419
Hospital stays	-0.10	-0.198 - -0.004	0.043	-0.09	-0.18–0.01	0.087

Note: RR, relative risk; CI, confidence interval; *P* value < 0.05; EBL, estimated blood loss

Table 3 Baseline demographic and clinical characteristics of the study participants with cyst sizes ≥ 10 cm and < 10 cm

Variables	Size ≥ 10 cm			Size < 10 cm		
	TU-LESS (*n* = 52)	MLS (*n* = 58)	*P*	TU-LESS(*n* = 184)	MLS (*n* = 234)	*P*
Symptom	4.00 ± 1.80	4.00 ± 2.00	0.70	0.00 ± 0.00	0.00 ± 0.00	0.36
CA125	19.86 ± 7.22	18.01 ± 7.90	0.68	14.80 ± 4.35	14.80 ± 4.25	0.44
HE4	63.94 ± 37.07	59.52 ± 30.51	0.10	44.55 ± 33.15	42.30 ± 37.10	0.64
Age	25.50 ± 37.00	33.00 ± 40.00	0.43	40.00 ± 19.00	37.00 ± 20.00	0.14
Unilateral	37 (71.29%)	48 (82.8%)	0.15	164(89.1%)	196(83.8%)	0.12
Bilateral	15 (82.8%)	10 (17.2%)		20(10.9%)	38 (16.2%)	
Procedure						
Unilateral salpingo oophorectomy	2 (3.8%)	1 (1.7%)	0.44	27 (14.7%)	21 (9.0%)	0.27
Unilateral ovarian cystectomy	27(51.9%)	35 (60.3%)		111 (60.3%)	145 (62.0%)	
Bilateral salpingo oophorectomy	16 (30.8%)	19 (32.8%)		27 (14.7%)	36 (15.4%)	
Bilateral ovarian cystectomy	7 (13.5%)	3 (5.2%)		19 (10.3%)	32 (13.7%)	
History						
Yes	8 (15.4%)	11 (19.0%)	0.62	146 (79.3%)	185 (79.1%)	0.94
No	44 (84.6%)	47 (81.0%)		38 (20.7%)	49 (20.9%)	
Pathology						
Serouscystadeno-ma	21(40.4%)	27 (46.6%)	0.91	78 (42.4%)	87 (37.2%)	0.21
Mucinouscystaden-oma	16 (30.8%)	18 (31.0%)		36 (19.6%)	45 (19.2%)	
Mature cystic teratoma	9 (17.3%)	9 (15.5%)		38 (20.7%)	47 (20.1%)	
Endometrioma	4 (7.7%)	3 (5.2%)		17 (9.2%)	40 (17.1%)	
Paroophoritic cyst	2 (3.8%)	1 (1.7%)		15 (8.2%)	15 (6.4%)	
BMI, kg/m^2	23.34 ± 3.38	23.48 ± 4.22	0.00	23.00 ± 4.38	24.00 ± 3.53	0.94

Note: Data are expressed as median (range), number (%) or mean ± standard deviation (SD)

BMI, Body Mass Index; CA125, carbohydrate antigen 125; HE4, human epididymis protein 4; SMD, standard mean difference

Table 4 Comparison of surgical outcomes before and after IPTW (TU-LESS group vs. MLS group) for (size ≥ 10 cm)

Variable	Before IPTW		
	RR	95%CI	*P*
Spillage rate	0.03	(0.00, 0.20)	< 0.001
Operation time	-12.48	(-20.00, -4.35)	0.003
EBL	-15.29	(-25.80, -4.78)	0.005
Pain	0.07	(-0.28, 0.42)	0.677
Hospital stays	-0.003	(-0.24, 0.24)	0.983

Note: RR, relative risk; CI, confidence interval; *P* value < 0.05; EBL, estimated blood loss

Table 5 Comparison of surgical outcomes before and after IPTW (TU-LESS group vs. MLS group) for (size < 10 cm)

Variables	Before IPTW		
	RR	95% CI	*P*
Spillage rate	12.34	2.31–65.94	0.003
Operation time	9.55	5.65–13.45	< 0.001
EBL	5.05	1.70–8.40	0.003
Pain	0.61	0.28–1.31	0.201
Hospital stays	-0.15	-0.31–0.01	0.070

Note: RR, relative risk; CI, confidence interval; *P* value < 0.05; EBL, estimated blood loss

will broaden our discussion to encompass these aspects, ensuring a thorough assessment of the method's implications on our research outcomes.

Although both TU-LESS and MLS are advanced laparoscopic techniques, our findings corroborate previous studies that fail to establish the superiority of LESS over MLS in aspects such as postoperative pain, intraoperative bleeding, conversion rates to laparotomy, hospital stay duration, cosmetic outcomes, with LESS notably requiring longer operation times [8, 11, 18]. These trends were echoed in our study, particularly for ovarian cysts smaller than 10 cm. The technical challenges posed by TU-LESS, like restricted triangulation and frequent instrument clashes, render MLS a more practical choice due to its greater flexibility and range of motion [19]. Notably, TU-LESS exhibits drawbacks when managing patients with severe endometriosis or extensive pelvic adhesions [20], emphasizing the importance of clearly communicating its risks and benefits to patients, particularly those with smaller ovarian cysts. Furthermore, the specialized training necessary for LESS techniques and the steep learning curve may elevate the risk of surgical complications. The limited accessibility of LESS in healthcare facilities could potentially delay timely interventions, while the elevated costs of the necessary equipment may strain healthcare budgets and hinder widespread adoption [21]. Despite these challenges, TU-LESS has been proven to be a safer and more viable option for managing large benign ovarian cysts [22], particularly in mitigating the risk of tumor rupture. Innovations, including purse-string suturing under direct visualization, have significantly reduced the likelihood of spillage during surgery. For instance, Chong GO et al. reported a notably lower spillage rate with TU-LESS compared to MLS (8.0% versus 69.7%) [21]. Similarly, our study achieved a lower intraoperative spillage rate of 1.9%, as opposed to 43.1% in the MLS group, by utilizing a sharper, thinner needle that facilitated the drainage of viscous fluid and prevented leaks during instrument exchanges.

The advantages of TU-LESS for managing large ovarian cysts are apparent. It facilitates cyst aspiration and deflation under direct visualization, thereby preventing spillage prior to removal [23, 24]. Additionally, TU-LESS offers the flexibility to perform cystectomy either extracorporeally or intracorporeally, which is particularly advantageous in cases of polycystic cysts [19]. When dealing with dense cystic contents, such as in large mature cystic teratomas containing bone fragments, cartilage, and hair, TU-LESS can efficiently extract the specimen. These benefits have translated into improved outcomes with TU-LESS, including reduced operation times, minimal blood loss, and lower spillage rates [25–27].

Despite these surgical benefits, our study found no notable disparities in postoperative pain or hospital stay duration between TU-LESS and MLS. This suggests that individual patient attributes and postoperative recovery dynamics may significantly impact these outcomes. Ascertaining a definitive difference in postoperative pain between TU-LESS and MLS is challenging, given that both procedures resulted in minimal pain post-adnexal surgery [28]. The comparable incision sizes employed in both techniques could also explain the similar levels of postoperative pain reported by patients [29]. Specifically, the total incision length in TU-LESS (2.5–3.0 cm in the umbilicus) mirrored that of MLS (1.0 cm in the umbilicus plus 0.5 cm each in three locations in the lower abdomen), suggesting comparable surgical invasiveness and trauma in both procedures.

This study boasts several strengths. Firstly, as a cohort study, it incorporated 528 patients and investigated the impact of surgical methods on benign ovarian cyst outcomes using IPTW and PS-matched analyses, effectively mitigating confounding factors. Secondly, it simultaneously evaluated numerous confounders and cyst size, potentially shedding light on the significance of cyst size in deciding between TU-LESS and MLS. However, this study also has limitations that warrant careful consideration. Firstly, we did not perform a formal sample size calculation, and it was conducted in a single-center setting which may limit the generalizability of the findings. Future multi-center, prospective studies are recommended to address this. Secondly, the conclusions are based on retrospective data, where EBL measurements, though standardized, may be subject to minor inaccuracies. Similarly, cystic spillage documentation relied on surgical records and video footage, potentially missing subtle spillage. Thirdly, while all surgeries were performed by three consistent surgeons, individual surgical expertise and background could have influenced the results [30]. Fourthly, due to variations in statistical methodologies and a notable dropout rate, this study did not encompass complications and recurrence rates. Additionally, the data spanned over a decade, during which our hospital's admission and discharge criteria underwent multiple revisions. Notably, the past two years have seen a shift towards day surgeries for ovarian cysts, contrasting with previous practices where patients typically stayed for 3 to 4 days, contributing to the absence of a statistical difference in hospital stay durations. Lastly, a limitation of inverse probability weighting lies in unmeasured confounders. Sensitivity analyses, such as calculating an E-value, can evaluate the impact of these unmeasured confounders on the estimated effect size [31].

Conclusion

In conclusion, TU-LESS posed a significantly higher risk of cystic content spillage and longer operation times compared to MLS. However, for ovarian cysts measuring 10 cm or larger, TU-LESS demonstrated a lower risk of cystic content spillage, shorter operation times, and reduced estimated blood loss (EBL) compared to MLS. Therefore, the performance of TU-LESS necessitates the involvement of more experienced surgeons.

Abbreviations

TU-LESS	Trans-umbilical laparo-endoscopic single-site surgery
MLS	Multiport laparoscopic surgery
IPTW	Inverse probability of treatment weighting
RR	Relative risk

CA125	Carbohydrate antigen 125
CT	Computed tomography
MRI	Magnetic resonance imaging
HE4	Human epididymis protein 4
SD	Standard deviation
PS	Propensity score

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Author contributions
Shuzhi Shan and Sufen Zhao carried out the studies, participated in collecting data, drafted the manuscript. Shuzhi Shan and Xiao Wang performed the statistical analysis and participated in its design. Shuzhi Shan participated in acquisition, analysis, or interpretation of data and draft the manuscript. All authors read and approved the final manuscript.

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Data availability
All data generated or analysed during this study are included in this article.

Declarations

Ethics approval and consent to participate
This study was approved by the Institutional Research Review Board of the Second Hospital of Hebei Medical University in China (2019-R087). All procedures performed in this study were in accordance with the Declaration of Helsinki. Signed informed consent forms were obtained from all participants. All methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Farghaly SA. Current diagnosis and management of ovarian cysts. Clin Exp Obstet Gynecol. 2014;41:609–12.
2. Cathcart AM, Nezhat FR, Emerson J et al. Adnexal masses during pregnancy: diagnosis, treatment, and prognosis. Am J Obstet Gynecol. 2022.
3. Sanchez AM, Vigano P, Somigliana E, et al. The distinguishing cellular and molecular features of the endometriotic ovarian cyst: from pathophysiology to the potential endometrioma-mediated damage to the ovary. Hum Reprod Update. 2014;20:217–30.
4. Parazzini F, Frattaruolo MP, Chiaffarino F, et al. The limited oncogenic potential of unilocular adnexal cysts: a systematic review and meta-analysis. Eur J Obstet Gynecol Reprod Biol. 2018;225:101–9.
5. Wang X, Li Y. Comparison of perioperative outcomes of single-port laparoscopy, three-port laparoscopy and conventional laparotomy in removing giant ovarian cysts larger than 15 cm. BMC Surg. 2021;21:205.
6. Zhao MZJ, Hua K, Zhu Z, Hu C. Single-incision multiport laparoscopy versus multichannel-tipped single port laparoscopy in gynecologic surgery: outcomes and benefits. Int J Clin Exp Med. 2015;8:14992–8.
7. Dai X, Zhang Y, Wang F, Luo Y, Gong Y. Effects of Umbilical Preparation Before Trans-umbilical Laparo-endoscopic Single-site Surgery on Umbilical Wounds Healing: a Randomized Controlled Trial. Surgical laparoscopy, endoscopy & percutaneous techniques. 2022;32:632-6.
8. Tsiampa E, Spartalis E, Tsourouflis G, Dimitroulis D, Nikiteas N. Impact on ovarian reserve after minimally invasive single-port laparoscopic ovarian cystectomy in patients with benign ovarian cysts: a systematic review and meta-analysis. Int J Clin Pract. 2021;75:e14875.
9. Murji A, Patel VI, Leyland N, Choi M. Single-incision laparoscopy in gynecologic surgery: a systematic review and meta-analysis. Obstet Gynecol. 2013;121:819–28.
10. Tang Y, Wen MB, Su B, et al. Early return to work: single-port vs. multiport laparoscopic surgery for benign ovarian tumor. Front Surg. 2022;9:1005898.
11. Lin Y, Liu M, Ye H, He J, Chen J. Laparoendoscopic single-site surgery compared with conventional laparoscopic surgery for benign ovarian masses: a systematic review and meta-analysis. BMJ Open. 2020;10:e032331.
12. Koo YJ. Recent advances in minimally invasive surgery for gynecologic indications. Yeungnam Univ J Med. 2018;35:150–5.
13. Yang L, Gao J, Zeng L, Weng Z, Luo S. Systematic review and meta-analysis of single-port versus conventional laparoscopic hysterectomy. Int J Gynaecol Obstet. 2016;133:9–16.
14. Schmitt A, Crochet P, Knight S, et al. Single-Port Laparoscopy vs Conventional Laparoscopy in Benign Adnexal diseases: a systematic review and Meta-analysis. J Minim Invasive Gynecol. 2017;24:1083–95.
15. Lim S, Lee KB, Chon SJ, Park CY. Is tumor size the limiting factor in a laparoscopic management for large ovarian cysts? Arch Gynecol Obstet. 2012;286:1227–32.
16. Henes M, Engler T, Taran FA, et al. Ovarian cyst removal influences ovarian reserve dependent on histology, size and type of operation. Womens Health (Lond). 2018;14:1745506518778992.
17. Shiota M, Kotani Y, Umemoto M, Tobiume T, Hoshiai H. Study of the correlation between tumor size and cyst rupture in laparotomy and laparoscopy for benign ovarian tumor: is 10 cm the limit for laparoscopy? J Obstet Gynaecol Res. 2012;38:531–4.
18. Eisenberg N, Volodarsky-Perel A, Brochu I, et al. Short- and long-term complications of Intraoperative Benign ovarian cyst spillage: a systematic review and Meta-analysis. J Minim Invasive Gynecol. 2021;28:957–70.
19. Zhang C, Duan K, Fang F et al. Comparison of Transvaginal and Transumbilical Laparoscopic single-site surgery for ovarian cysts. JSLS. 2021;25.
20. Huang Y, Duan K, Koythong T, et al. Application of robotic single-site surgery with optional additional port for endometriosis: a single institution's experience. J Robot Surg. 2022;16:127–35.
21. Chong GO, Hong DG, Lee YS. Single-port (OctoPort) assisted extracorporeal ovarian cystectomy for the treatment of large ovarian cysts: compare to conventional laparoscopy and laparotomy. J Minim Invasive Gynecol. 2015;22:45–9.
22. Lee SR. Fast Leak-Proof, Intraumbilical, single-incision laparoscopic ovarian cystectomy for huge ovarian masses: Hybrid Cystectomy and Reimplantation Method. Med (Kaunas). 2021;57.
23. Kim JS, Lee IO, Eoh KJ, et al. Surgical technique for single-port laparoscopy in huge ovarian tumors: SW Kim's technique and comparison to laparotomy. Obstet Gynecol Sci. 2017;60:178–86.
24. Ki EY, Park EK, Jeong IC, et al. Laparoendoscopic single site surgery for the treatment of huge ovarian cysts using an Angiocatheter needle. Yonsei Med J. 2019;60:864–9.
25. Cho BR, Han JW, Kim TH, et al. Single port access laparoscopic surgery for large adnexal tumors: initial 51 cases of a single institute. Obstet Gynecol Sci. 2017;60:32–8.
26. Song T, Sung JH. Leak-proof technique in laparoscopic surgery for large ovarian cysts. J Obstet Gynaecol. 2021;41:106–11.
27. Song T, Kim MK, Kim ML, Yoon BS, Seong SJ. Laparoendoscopic single-site surgery for extremely large ovarian cysts: a feasibility, safety, and patient satisfaction study. Gynecol Obstet Invest. 2014;78:81–7.
28. Richards L, Healey M, Cheng C, Dior U. Laparoscopic oophorectomy to treat Pelvic Pain FollowingOvary-Sparing hysterectomy: factors Associated with Surgical complications and Pain Persistence. J Minim Invasive Gynecol. 2019;26:1044–9.
29. Kliethermes C, Blazek K, Ali K et al. Postoperative Pain after single-site Versus Multiport Hysterectomy. JSLS. 2017;21.

30. Dughayli M, Shimunov S, Johnson S, Baidoun F. Single-site robotic cholecystectomy: comparison of clinical outcome and the learning curves in relation to surgeon experience in a community teaching hospital. BMC Surg. 2018;18:39.
31. VanderWeele TJ, Ding P. Sensitivity analysis in Observational Research: introducing the E-Value. Ann Intern Med. 2017;167:268–74.

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