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Jiankui Li
the 960th Hospital of the PLA Joint Logistic Support Force
Juan Li
the 960th Hospital of the PLA Joint Logistic Support Force
Shuhong Zhang
186788593590163.com

the 960th Hospital of the PLA Joint Logistic Support Force

Research Article

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Posted Date: November 4th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10949033/v1

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Additional Declarations: No competing interests reported.

Blinded cosmetic comparison of four suture techniques for umbilical reconstruction in TU-LESS

Jiankui Li[1†], Juan Li[1†], Shuhong Zhang[1*]

1 Department of Obstetrics and Gynecology, the 960th Hospital of the PLA Joint Logistic Support Force, Jinan 250031, Shandong Province, China

† Jiankui Li and Juan Li contributed equally to this work.

** Correspondence: Shuhong Zhang, Department of Obstetrics and Gynecology, the 960th Hospital of the PLA Joint Logistic Support Force, Jinan 250031, Shandong Province, China. E-mail: 18678859359@163.com*

Abstract

Background: Transumbilical laparoendoscopic single-site surgery (TU-LESS) conceals the incision within the umbilicus, but umbilical hernia, wound infection, and distortion remain concerns, and no consensus exists on the optimal reconstruction technique. We compared four suture techniques for their perioperative and blinded cosmetic outcomes after TU-LESS.

Methods: This retrospective study included 525 patients who underwent TU-LESS between February 2023 and February 2025. By the operating surgeon's preference, patients received double figure-of-eight anchoring (group A, n=133), single figure-of-eight (group B, n=131), double-U anchoring (group C, n=129), or continuous suturing (group D, n=132). Complications, umbilical suturing time, total operative time, and postoperative pain scores were recorded and summarised by technique. Umbilical appearance was assessed at one month postoperatively with the Patient and Observer Scar Assessment Scale (POSAS) by two independent physicians blinded to group allocation, surgeon identity, and timing; the observer scale comprises six items scored 1–10, and the mean item score (lower = better) is reported.

Results: Complications occurred in 12 of 525 patients (2.29%), with no intergroup difference (all P>0.05). Umbilical suturing time (7.0±1.7, 5.3±1.3, 6.9±1.8, and 4.5±1.0 min; H=188.517) and the mean POSAS observer score (3.6±1.1, 3.2±1.0, 3.7±1.2, and 3.0±1.0; F=11.252) differed significantly across groups (both P<0.001); continuous and single figure-of-eight suturing were associated with the shortest suturing times and the lowest (best) observer scores. The blinded cosmetic satisfaction rate was 95.4% (501/525), with no intergroup difference (χ^2=0.994, P=0.803).

Conclusions: All four techniques were used without a technique-specific safety signal in this series. Continuous and single figure-of-eight suturing were associated with the shortest suturing times and the lowest blinded POSAS observer scores. Blinded assessment is warranted, because the surgeons' unblinded impressions (favouring group A) were inconsistent with the blinded results (favouring group D). Given the retrospective, non-randomized, single-centre design, these findings require confirmation in prospective multicentre studies.

Keywords: Transumbilical laparoendoscopic single-site surgery; Umbilical reconstruction; Suture technique; Umbilical hernia; Surgical site infection; Cosmetic assessment

Background

Transumbilical laparoendoscopic single-site surgery (TU-LESS) places the incision within the umbilicus, combining the benefits of minimal invasiveness with excellent cosmesis, and its use for benign and malignant gynecologic conditions is expanding [1–3]. However, because the umbilicus is a naturally weak point of the abdominal wall, postoperative complications including umbilical hernia, wound infection, and umbilical distortion still occur: the overall incidence of umbilical wound complications after TU-LESS has been reported to be 2%–10% [4], with the incidence of incisional hernia alone varying widely from 0.1% [4] to 2.2% [5], which is one of the factors limiting wider adoption of this technique. Meanwhile, patients increasingly prioritize cosmesis [6], and the umbilicus, as the only visible "scar" on the abdomen, directly influences postoperative body image and satisfaction [7, 8]. Although consensus on umbilical wound management has been established [4], and various umbilical reconstruction techniques—including anchor suturing [9], the Sturmdorf suture [10], and quilting suture [11]—have been reported, most are single-technique case series, and parallel comparisons of multiple suture techniques for perioperative and cosmetic outcomes in a large sample are scarce, particularly those using blinded, objective cosmetic assessment by independent evaluators. Therefore, we retrospectively analysed 525 patients who underwent TU-LESS to describe the complications, perioperative outcomes, and blinded cosmetic outcomes associated with four umbilical reconstruction techniques and to inform individualized umbilical shape design.

Methods

Study design and patients

This retrospective study included 525 patients who underwent TU-LESS successfully at the Department of Gynecology of our hospital between February 2023 and February 2025, including 256 hysterectomies, 145 ovarian cystectomies, 60 salpingectomies, 52 myomectomies, and 12 staging procedures for endometrial cancer. All surgeries were performed by two surgeons, who selected one of four suture techniques for umbilical reconstruction according to the patient's umbilical morphology and their own experience: 133 patients underwent the double figure-of-eight anchoring technique, 131 the single figure-of-eight technique, 129 the double-U anchoring technique, and 132 continuous suturing. The study was approved by the Medical Ethics Committee of our hospital (approval no. 2024 KYL-050), and written informed consent was obtained from all patients. Because the groups were assigned according to surgeon preference rather than by randomization, surgeon and technique are potentially confounded; we therefore report all between-technique contrasts as associations, and the implications are set out in the Limitations.

Surgeon identity was not captured in the study database and was recovered retrospectively from the operating theatre logbook and the electronic anaesthesia record for all 525 procedures. Surgeon 1 performed 266 procedures and surgeon 2 performed 259, and both surgeons used all four techniques; the between-surgeon distribution is presented in the Results section.

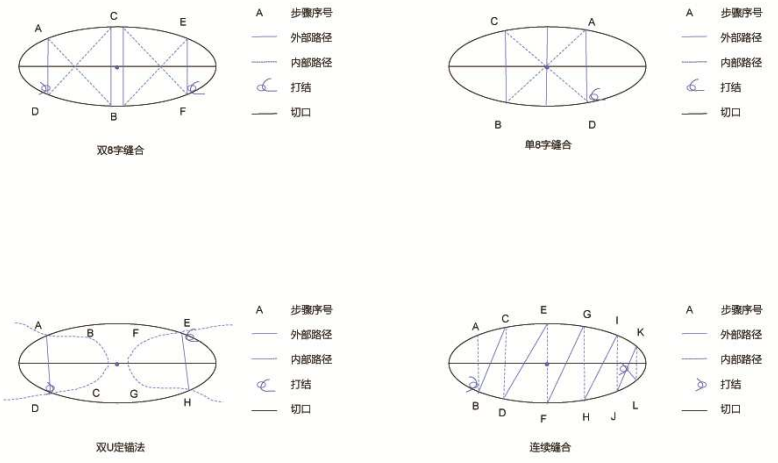
Preoperative preparation

On the day before surgery, the umbilical fossa was cleaned with liquid paraffin. Before skin incision, the umbilicus was everted until the fossa was fully exposed, and the area was disinfected again with iodophor, taking care to avoid damaging the periumbilical skin.

Surgical technique

Umbilical incision. After eversion of the umbilicus, two towel clamps were placed approximately 2–3 mm lateral to the centre of the umbilicus for symmetric traction. The skin was incised longitudinally or transversely with a scalpel (2.0–3.5 cm, mostly 2.5–3.0 cm), and the fascia and peritoneum were opened layer by layer. After entering the abdominal cavity, the periumbilical area was checked digitally for adhesions, the peritoneal incision was progressively extended beyond the skin incision, and a dedicated TU-LESS port (access platform) was placed before completing the procedure.

Umbilical reconstruction. (1) Double figure-of-eight anchoring: the peritoneum was closed with continuous suture and the fascia with interrupted sutures (3–5 mm spacing). After exposure of the bilateral umbilical skin flaps, a 2-0 absorbable suture was passed through the fascia at the margin of the umbilical ring on one side and out approximately 2 mm from the dermal edge of the contralateral flap; an inner figure-of-eight suture was placed superiorly and inferiorly relative to the umbilical midpoint to anchor the umbilicus. The remaining subcutaneous tissue was closed with figure-of-eight sutures, and the skin with 4-0 subcuticular suture or tissue adhesive. (2) Single figure-of-eight: the peritoneum and fascia were closed as above. A 2-0 absorbable suture was passed through the fascia at the margin of the umbilical ring on one side (point A) and out approximately 2 mm from the contralateral dermal edge (point B), then from point C to point D, completing a single figure-of-eight suture. (3) Double-U anchoring: the peritoneum and fascia were closed as above. A 2-0 absorbable suture was passed through the fascia at the margin of the umbilical fossa and out approximately 2 mm from the ipsilateral dermal edge, advancing to the umbilical midpoint, then through the contralateral dermal edge and out through the fascia, and tied; a U-shaped suture was completed on the other side in the same manner. (4) Continuous suture: the peritoneum and fascia were closed as above; a 2-0 absorbable suture was run continuously from one end of the incision to the other with approximately 5 mm spacing, and the skin was closed with 4-0 subcuticular suture or tissue adhesive. The four techniques are illustrated schematically in Fig. 1.



Outcome measures

Within 2 months postoperatively, wound healing, wound infection, wound bleeding, and umbilical hernia were observed, with long-term follow-up for hernia. For suspected wound infection, microbiological culture of wound secretions was performed and antibiotics were selected accordingly. Umbilical hernia was assessed by the patient's report of umbilical bulging and ultrasonography. Umbilical suturing time (from the start of umbilical suturing to completion of skin closure), total operative time (from skin incision to completion of suturing), postoperative hospital stay (days), and resting pain scores (visual analogue scale [VAS], 0–10) at 24 h and 48 h were recorded from medical and anaesthesia records by a research assistant to avoid operator bias.

Blinded cosmetic assessment was performed one month postoperatively using the Patient and Observer Scar Assessment Scale (POSAS) [12]. Two independent physicians who did not participate in the surgery scored de-identified photographs of the umbilicus (blinded to group allocation, surgeon identity, and timing) on six items—vascularity, pigmentation, thickness, relief, pliability, and surface area—each scored 1–10; overall opinion was recorded separately and was not included in the mean. The arithmetic mean of the six items (range 1–10, lower indicating better appearance) was used as the observer score. Patients completed the patient component of the POSAS, also reported as the mean item score. The two physicians' scores were averaged; if the mean scores differed by more than 1 point, a third independent physician arbitrated.

Statistical analysis

Statistical analyses were performed with SPSS 25.0. Continuous variables are presented as mean ± standard deviation. Normality was assessed with the Shapiro–Wilk test and homogeneity of variance with Levene's test; variables meeting both assumptions were compared with one-way ANOVA, otherwise with the Kruskal–Wallis test. Categorical variables are presented as frequency and percentage and were compared with the χ^2 test or Fisher's exact test (Monte Carlo, 10 000 samples) when more than 20% of expected frequencies were below 5. Three co-primary outcomes were prespecified: (1) overall complications, (2) umbilical suturing time, and (3) POSAS observer score, to evaluate both safety and cosmetic outcomes. To control the inflation of type I error from multiple comparisons, Bonferroni correction was applied with k=3, giving a corrected significance level of $\alpha=0.0167$. Hospital stay, VAS scores, and total operative time were prespecified as secondary exploratory outcomes; their P values were not corrected for the primary endpoint and are reported descriptively. Analyses were reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [13]. $P<0.05$ was considered statistically significant.

Because technique was chosen by surgeon preference rather than assigned at random, we examined whether surgeon confounded the between-technique contrasts. In addition to the unadjusted analysis, we fitted models that entered surgeon as a fixed effect together with the case-mix covariates (age, BMI, diabetes, autoimmune disease or long-term corticosteroid use, type of surgery, incision length, and preoperative umbilical shape). We did not fit surgeon as a random effect, because with two surgeons the between-surgeon variance is not estimable with useful precision. Surgeon-adjusted estimates are reported alongside the unadjusted estimates; a change in the direction or ordering of the technique coefficients after surgeon adjustment would indicate confounding by surgeon.

During the preparation of this work the authors used an AI-based language tool to assist with language editing and manuscript formatting. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Results

The four groups were comparable in body mass index, diabetes, autoimmune disease/long-term corticosteroid use, type of surgery, and preoperative umbilical morphology (all P>0.05), but differed in age (H=8.046, P=0.045; group A 46.8±8.2 vs group D 50.1±11.0 years) and umbilical incision length (H=15.810, P=0.001) (Table 1). Because age is a potential risk factor for poor wound healing and infection, and because group assignment was based on surgeon preference rather than randomization, binary logistic regression with adjustment for age was performed with any complication as the dependent variable and group (A as reference) as the independent variable; the risk of complications in groups B, C, and D did not differ significantly from group A (95% confidence intervals of the adjusted odds ratios all crossed 1, all P>0.05), suggesting that age imbalance did not explain the observed group differences in complications, although this regression was exploratory owing to the small number of events.

Table 1. Baseline characteristics of the four groups

Variable	A (n=133)	B (n=131)	C (n=129)	D (n=132)	Statistic	P
Age (y), mean±SD	46.8±8.2	48.4±9.8	48.8±8.5	50.1±11.0	H=8.046	0.045
BMI (kg/m²), mean±SD	24.5±3.4	23.5±3.6	23.6±3.3	23.7±3.1	F=2.345	0.072
Diabetes, n (%)	6 (4.51)	5 (3.82)	4 (3.10)	5 (3.79)	Fisher	0.989
Autoimmune/long-term steroids, n (%)	3 (2.26)	4 (3.05)	2 (1.55)	3 (2.27)	Fisher	0.942
Surgery – hysterectomy, n (%)	65 (48.87)	63 (48.09)	62 (48.06)	66 (50.00)	χ^2=3.004	0.996
Surgery – ovarian cystectomy, n (%)	37 (27.82)	36 (27.48)	35 (27.13)	37 (28.03)		
Surgery – salpingectomy, n (%)	15 (11.28)	15 (11.45)	15 (11.63)	15 (11.36)		
Surgery – myomectomy, n (%)	13 (9.77)	14 (10.69)	12 (9.30)	13 (9.85)		
Surgery – endometrial cancer staging, n (%)	3 (2.26)	3 (2.29)	5 (3.88)	1 (0.76)		
Umbilical incision length (cm), mean±SD	2.7±0.3	2.7±0.4	2.8±0.3	2.7±0.4	H=15.810	0.001
Preop. umbilical shape – round, n (%)	34 (25.56)	32 (24.43)	33 (25.58)	31 (23.48)	χ^2=0.695	1.000
Preop. umbilical shape – oval, n (%)	27 (20.30)	26 (19.85)	26 (20.16)	26 (19.70)		
Preop. umbilical shape – vertical, n (%)	20 (15.04)	20 (15.27)	19 (14.73)	21 (15.91)		
Preop. umbilical shape –	27 (20.30)	26 (19.85)	26 (20.16)	26 (19.70)		

depressed, n (%)						
Preop. umbilical shape – protruding, n (%)	14 (10.53)	14 (10.69)	13 (10.08)	14 (10.61)		
Preop. umbilical shape – irregular, n (%)	11 (8.27)	13 (9.92)	12 (9.30)	14 (10.61)		

Age and umbilical incision length showed unequal variances (Levene $P<0.05$) and were analysed with the Kruskal–Wallis test; BMI showed equal variances and was analysed with ANOVA. Type of surgery and preoperative umbilical shape are multi-category variables compared with 4×5 and 4×6 contingency-table χ^2 tests (df=12 and 15, respectively); the statistic is shown in the first row of each variable and applies to all subcategories.

Because the operating surgeon selected the technique, we examined the distribution of the four suture techniques between the two surgeons (Table 2).

Table 2. Distribution of the four suture techniques by operating surgeon.

Surgeon	**A (n=133)**	**B (n=131)**	**C (n=129)**	**D (n=132)**	**Total**
Surgeon 1	68 (25.6/51.1)	65 (24.4/49.6)	67 (25.2/51.9)	66 (24.8/50.0)	266
Surgeon 2	65 (25.1/48.9)	66 (25.5/50.4)	62 (23.9/48.1)	66 (25.5/50.0)	259
Total	133	131	129	132	525

Values are numbers of procedures, with the percentage of the surgeon's own caseload and the percentage of the technique's total in parentheses. Both surgeons used all four techniques. The technique mix was similar between the two surgeons ($\chi^2 = 0.176$, df = 3, $P = 0.981$; Cramér's $V = 0.018$).

Complications occurred in 12 of 525 patients (2.29%), each a single event without overlap: wound infection in 4 (0.76%; 3 Staphylococcus aureus and 1 Escherichia coli), delayed wound healing in 6 (1.14%), wound bleeding in 1 (0.19%), and one umbilical hernia (0.19%) detected 10 months postoperatively during a median follow-up of 12 months (range 6–30 months). None of these complications differed significantly among groups (all $P>0.05$; Fisher's exact test; Table 3). The blinded cosmetic satisfaction rate was 95.4% (501/525), with no intergroup difference (Table 4). Representative intraoperative and one-month postoperative appearances are shown in Fig. 2.

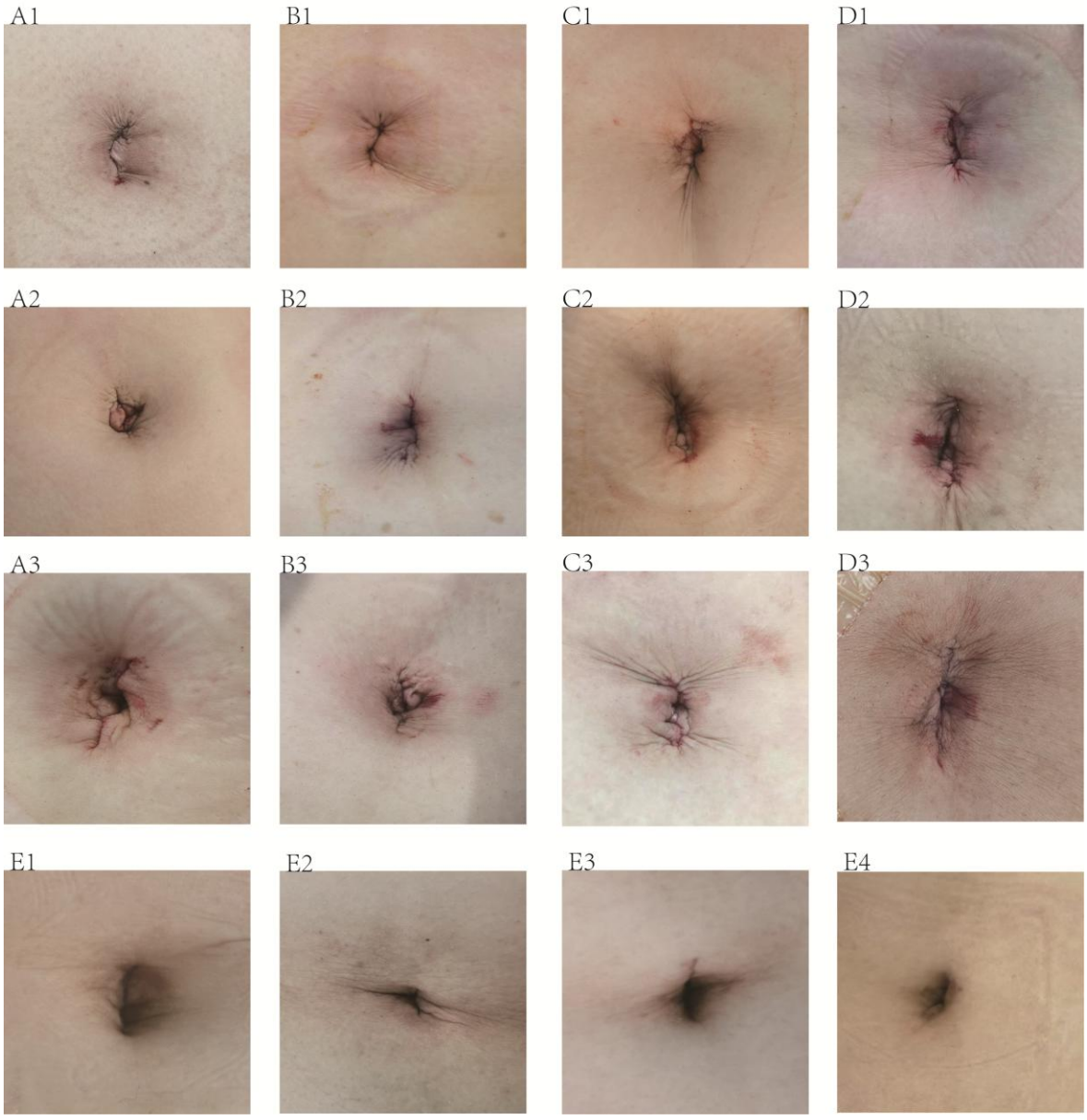


Table 3. Postoperative complications by group [n (%)]

Outcome	A (n=133)	B (n=131)	C (n=129)	D (n=132)	P
Wound infection	1 (0.75)	1 (0.76)	0 (0.00)	2 (1.52)	0.857*
Delayed wound healing	2 (1.50)	1 (0.76)	1 (0.78)	2 (1.52)	1.000*
Wound bleeding	1 (0.75)	0 (0.00)	0 (0.00)	0 (0.00)	1.000*
Umbilical hernia	0 (0.00)	1 (0.76)	0 (0.00)	0 (0.00)	0.495*
Overall complications	4 (3.01)	3 (2.29)	1 (0.78)	4 (3.03)	0.578*

* Fisher's exact test (Monte Carlo, 10 000 samples; the minimum expected frequency was <5 in all rows). All 12 complications were single events without overlap; the umbilical hernia occurred during the 6–30-month follow-up period, whereas the other events occurred within 2 months postoperatively.

The umbilical suturing time, total operative time, hospital stay, VAS scores, POSAS observer score, and blinded cosmetic satisfaction rate are summarised in Table 4. The mean POSAS observer scores were 3.6±1.1, 3.2±1.0, 3.7±1.2, and 3.0±1.0 in groups A–D, respectively ($F=11.252$, $P<0.001$, $\eta^2=0.061$); pairwise comparison showed that groups D and B scored more favourably than groups A and C (Bonferroni-corrected $P<0.05$), whereas groups D and B did not differ significantly (mean difference 0.14, 95% CI −0.11 to 0.38; uncorrected independent-samples t test, $P=0.267$). The patient self-rated POSAS scores (4.0±1.3, 3.7±1.5, 4.2±1.7, and 3.9±1.3) did not differ significantly ($H=5.516$, $P=0.138$), nor did the blinded cosmetic satisfaction rate ($\chi^2=0.994$, $P=0.803$). The intergroup difference in total operative time (7.9 min between groups A and D) exceeded that in umbilical suturing time (2.5 min), suggesting that the difference in total operative time was not entirely attributable to the suturing step and may reflect unmeasured factors; therefore, it is reported descriptively only.

Table 4. Perioperative outcomes and blinded cosmetic assessment by group

Variable	A	B	C	D	Statistic	P
Suturing time (min), mean±SD	7.0±1.7	5.3±1.3	6.9±1.8	4.5±1.0	H=188.517	<0.001
Total operative time (min), mean±SD	87.8±15.3	82.6±14.1	86.3±16.0	79.9±13.0	F=7.763	<0.001
Hospital stay (d), mean±SD	3.3±0.9	3.1±0.7	3.3±0.8	3.0±0.5	H=7.900	0.048
VAS at 24 h, mean±SD	3.2±1.1	2.8±0.9	3.0±1.3	2.8±0.9	H=11.915	0.008
VAS at 48 h, mean±SD	1.8±0.8	1.6±0.7	2.0±0.9	1.6±0.6	H=17.180	<0.001
POSAS observer score, mean±SD	3.6±1.1	3.2±1.0	3.7±1.2	3.0±1.0	F=11.252	<0.001
POSAS patient score, mean±SD	4.0±1.3	3.7±1.5	4.2±1.7	3.9±1.3	H=5.516	0.138
Blinded cosmetic satisfaction, n (%)	125 (93.98)	126 (96.18)	123 (95.35)	127 (96.21)	$\chi^2=0.994$	0.803

Suturing time, hospital stay, VAS, and POSAS patient score showed unequal variances (Levene $P<0.05$) and were analysed with the Kruskal–Wallis test; total operative time and POSAS observer score showed equal variances and were analysed with ANOVA. POSAS scores are the arithmetic mean of six items (range 1–10), not the total score. Overall complications, suturing time, and POSAS observer score were prespecified primary outcomes (Bonferroni-corrected $\alpha=0.0167$, $k=3$); total operative time, hospital stay, and VAS were secondary exploratory outcomes with uncorrected P values and limited absolute intergroup differences (0.22 d and 0.38–0.40 points, respectively), which are below accepted minimal clinically important differences. Pairwise comparisons of the POSAS observer score used Bonferroni correction ($k=6$, $\alpha=0.0083$): groups D and B scored more favourably than groups A and C, whereas D and B did not differ significantly.

The direction and ordering of the between-technique contrasts were unchanged after adjustment for operating surgeon and case mix. With technique A as the reference, the surgeon-adjusted differences for continuous suturing were −2.47 min (95% CI −2.83 to −2.11; $P < 0.001$) for suturing time and −0.53 points (95% CI −0.79 to −0.26; $P < 0.001$) for the blinded POSAS observer score, and the between-surgeon component of variance was negligible (intraclass correlation 0.003 for suturing time and 0.004 for the POSAS observer score).

Discussion

In this study of 525 patients, four umbilical reconstruction techniques were compared after TU-LESS. First, the four groups did not differ significantly in overall complications, wound infection, or delayed wound healing (all

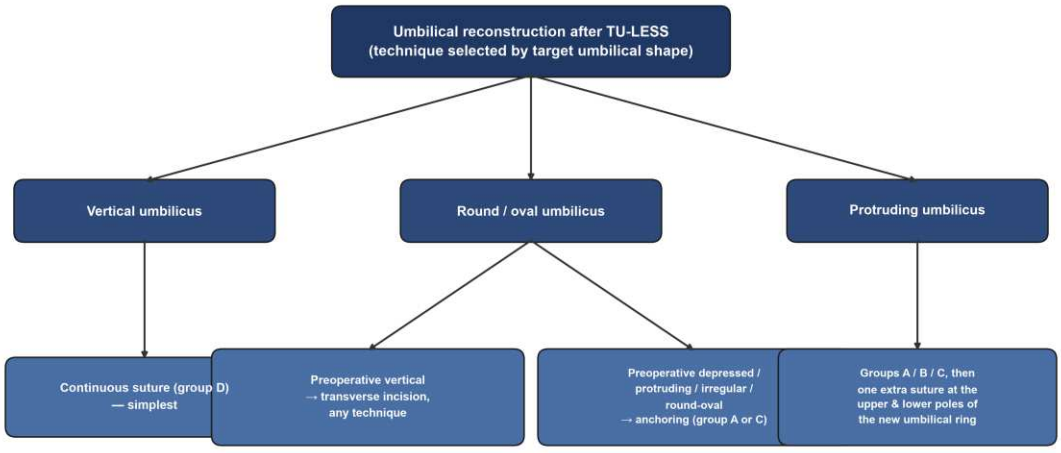
P>0.05), with 12 complications overall (2.29%), suggesting comparable short-term safety. Second, umbilical suturing time (7.0, 5.3, 6.9, and 4.5 min in groups A–D) and the blinded POSAS observer score (3.6, 3.2, 3.7, and 3.0) differed significantly (both P<0.001), with continuous suturing (group D) associated with the shortest suturing time and the lowest (best) observer score. The ordering of suturing times across techniques follows the number of sutures each technique requires, which is compatible with, but does not establish, a difference in technical ease of execution; the difference in total operative time (7.9 min) exceeded that in suturing time (2.5 min) and should not be interpreted as evidence of a difference in efficacy. Third, the surgeons' unblinded impression (favouring group A as closest to the original umbilical shape) was inconsistent with the blinded POSAS results, which favoured group D (3.0) and B (3.2) over groups A (3.6) and C (3.7). This discrepancy highlights the need for blinded assessment: surgeons' evaluation of their own technique is difficult to free from knowledge of group allocation, learning curve, and personal investment, and reliance on unblinded impressions may lead to recommendations opposite to objective evidence. In addition, the blinded cosmetic satisfaction rate (95.4%) was an independent measure not collinear with complications; the 24 dissatisfied patients had no wound-related complications, and their dissatisfaction was mainly attributable to a postoperative umbilical shape falling short of expectation.

Concerning prevention of umbilical hernia, the overall incidence of umbilical wound complications after TU-LESS has been reported as 2%–10% [4]. For incisional hernia alone, estimates vary: a meta-analysis of 19 randomized trials (1705 patients) reported a trocar-site hernia rate of 2.2% for single-incision versus 0.7% for conventional laparoscopy (odds ratio 2.26, 95% CI 1.00–5.08) [5]; Noh et al. observed only 3 hernias among 2498 Asian patients (0.12%) [14]; Zhu et al. reported 0.357% for single-incision versus 0.013% for conventional laparoscopy [15]; and Gunderson et al. reported 2.4%, falling to 0.5% after excluding high-risk patients [16]. A multicentre Chinese series of 10 808 cases reported an umbilical hernia rate of 0.1% [4]. Our rate of 0.19% (1/525) is close to these Asian data. However, this should be interpreted cautiously: there was only one event, and routine imaging screening was not performed in all patients (ultrasonography was performed only for symptomatic bulging), so asymptomatic hernias may have been systematically underestimated. All four techniques in our study closed the abdominal wall in three layers (peritoneum, fascia, and skin) to restore the native umbilical anatomy, with attention to closing both edges of the peritoneum and fascia without gaps; however, no control group without layered closure was available, so this technical point remains experiential. Given a median follow-up of only 12 months (range 6–30 months), late hernias cannot be excluded, and follow-up of this cohort is ongoing.

Concerning prevention of wound infection, a reported infection rate after TU-LESS is 0.93% [4]; our rate was 0.76% (4/525). With only four events and no statistical comparison with the literature, and with the four infections scattered across the study period without temporal clustering, we cannot conclude that our protocol reduced infection risk. Our preventive measures included full eversion and repeated disinfection of the umbilical fossa before incision, gentle handling to avoid skin injury, re-disinfection after reconstruction, perioperative control of comorbidities such as diabetes, renal disease, and immune disorders [17–19], avoidance of energy devices during umbilical incision and hemostasis, and red-light irradiation after dressing changes from postoperative day 2 (performed according to our routine protocol; specific parameters were not uniformly recorded). Although red-light therapy has been studied in wound healing [20, 21], all 525 patients received it

without a control group, so its effect on infection or healing cannot be assessed from our data, and this measure remains empirical pending randomized evaluation.

Regarding individualized umbilical shape, the umbilicus directly influences body image and satisfaction [7, 8], and quilting suture during wound closure has also been shown to improve the postoperative umbilical shape [11]. Our experience suggests that specific suture techniques can reconstruct the umbilicus into round, oval, vertical, or protruding shapes: continuous suturing is simplest for a vertical umbilicus; for a round or oval target shape, a transverse incision with any technique is feasible when the preoperative umbilicus is vertical, whereas anchoring techniques (groups A or C) are preferable for depressed, protruding, irregular, or round/oval preoperative shapes; a protruding umbilicus can be created by placing an additional suture at the superior and inferior poles of the new umbilical ring down to the fascial base after fascial closure in groups A, B, or C (Fig. 3). Two points should be emphasized. First, these recommendations and the ring-size considerations given in the Fig. 3 note are based on the experience of our two surgeons; we did not stratify by umbilical ring size or formally test the interaction between preoperative shape and technique, so they are experiential and require prospective validation. Second, the four groups were highly balanced in preoperative umbilical morphology (P=1.000, Table 1), indicating that technique selection in practice did not strictly follow a shape-matching rule; the proposed strategy is therefore a testable path derived from our experience rather than a finding validated by the present data. Finally, umbilical reconstruction is influenced by skin laxity, scar tendency, and preoperative shape, and patients should be counselled preoperatively that the cosmetic outcome may fall short of expectation.



Regarding whether to pre-place traction sutures at the peritoneal edges, this remains experiential: we did not compare with and without pre-placed sutures, and no related outcome was recorded. With adequate muscle relaxation (by requesting additional muscle relaxant about 10 min before closure), the peritoneum was readily exposed and elevated with four Allis clamps, so we do not routinely pre-place sutures; for patients with severe

obesity, however, pre-placed sutures may facilitate peritoneal closure. Elevating the port to retract the peritoneum, as described by Zheng et al. [9], is also effective.

This study has several limitations. First, it was retrospective, single-centre, and non-randomized, with group assignment based on surgeon preference and with baseline differences in age and incision length; surgeon and technique were confounded in principle, but surgeon identity was recovered retrospectively from the operating theatre logbook and the electronic anaesthesia record for all 525 procedures. The technique mix was closely similar between the two surgeons (Table 2), the between-surgeon component of variance in the outcomes was negligible (intraclass correlation 0.003 for suturing time and 0.004 for the blinded POSAS observer score), and the direction and ordering of all between-technique contrasts were unchanged after adjustment for surgeon. These observations bound, but do not exclude, residual confounding, and the between-technique differences are therefore reported as associations rather than as effects of technique. Because the dataset was not ordered by operation date and the temporal boundary of the learning curve could not be defined, no sensitivity analysis excluding learning-phase cases was performed; instead, binary logistic regression adjusting for age showed no significant difference in complications between groups B, C, and D versus A (all 95% CIs crossed 1, all $P>0.05$), although the model was unstable owing to only 12 events and an inadequate number of events per variable, and these results are exploratory. Second, we report uncorrected P values for transparency; with the prespecified Bonferroni correction for the three co-primary outcomes ($k=3$, $\alpha=0.0167$), the significant differences in suturing time and POSAS observer score (both $P<0.001$) remained significant at the corrected threshold, whereas overall complications did not differ. Third, umbilical hernia was not screened by routine imaging, so asymptomatic hernias may have been underestimated, the most likely explanation for our low hernia rate. Fourth, although the blinded POSAS observer score differed significantly among groups, the range of means was only 0.7 points with a limited effect size ($\eta^2=0.061$), and no minimal clinically important difference was prespecified, and the assessment at one month may not reflect the final cosmetic outcome, as scar maturation typically requires 6–12 months. Fifth, blinded assessment was based on static photographs and did not capture sensation, texture, or objective umbilical depth. Sixth, all surgeries were performed by two senior surgeons in a single centre, limiting generalizability to community settings or teams in the early learning curve. Seventh, no sample-size calculation or health-economic evaluation was performed. Eighth, the follow-up was relatively short for late complications such as hernia.

Conclusions

All four suture techniques were feasible for umbilical reconstruction after TU-LESS in this series, with a low short-term complication rate and high blinded cosmetic satisfaction. Continuous and single figure-of-eight suturing were associated with the shortest suturing times and favourable blinded cosmetic outcomes; our experience suggests that the umbilical shape can be tailored to the preoperative morphology. Blinded cosmetic assessment is warranted, because surgeons' unblinded impressions may differ from objective results. Given the retrospective design, prospective multicentre studies are needed to validate the long-term outcomes and the individualized selection strategy.

List of abbreviations

TU-LESS: transumbilical laparoendoscopic single-site surgery; POSAS: Patient and Observer Scar Assessment Scale; VAS: visual analogue scale; BMI: body mass index; ANOVA: analysis of variance; CI: confidence interval; STROBE: Strengthening the Reporting of Observational Studies in Epidemiology.

Declarations

Ethics approval and consent to participate

This study was approved by the Medical Ethics Committee of the 960th Hospital of the PLA Joint Logistic Support Force (approval no. 2024 KYL-050). Written informed consent was obtained from all participants. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable. All clinical photographs are restricted to anonymized umbilical-region images; no identifiable patient information (face, tattoo, hospital wristband, or metadata) is shown.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This study was supported by the Jinan Maternal and Child Health Science and Technology Project (grant no. JNFYBJXH-2026Y009).

Authors' contributions

Jiankui Li: study conception, surgery, data collection, and manuscript drafting; Juan Li: data analysis and interpretation, and critical revision of the manuscript; Shuhong Zhang: study design, manuscript revision, and final approval, corresponding author. All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

References

1. Lin Y, Liu M, Ye H, et al. Laparoendoscopic single-site surgery compared with conventional laparoscopic surgery for benign ovarian masses: a systematic review and meta-analysis. BMJ Open. 2020;10(2):e032331.

2. Jiang D, Yang Y, Zhang X, et al. Laparoendoscopic single-site compared with conventional laparoscopic surgery for gynaecological acute abdomen in pregnant women. J Int Med Res. 2021;49(10):03000605211053985.

3. Cooperative Group of Gynecologic Laparoendoscopic Single-Site Surgery, Chinese Society of Obstetrics and Gynecology, Chinese Medical Association. Expert consensus on gynecologic laparoendoscopic single-site surgery (including vNOTES) (2025 edition). [Article in Chinese]. Zhonghua Fu Chan Ke Za Zhi. 2025;60(6):417–421.

4. Single-Port and Vaginal Endoscopy Group, Minimally Invasive and Non-Invasive Medicine Committee, Chinese Medical Doctor Association. Expert consensus on umbilical incision management in transumbilical laparoendoscopic single-site surgery (2022 edition). [Article in Chinese]. J Pract Obstet Gynecol. 2022;38(3):192–197.

5. Antoniou SA, Morales-Conde S, Antoniou GA, et al. Single-incision laparoscopic surgery through the umbilicus is associated with a higher incidence of trocar-site hernia than conventional laparoscopy: a meta-analysis of randomized controlled trials. Hernia. 2016;20(1):1–10.

6. Goebel K, Goldberg JM. Women's preference of cosmetic results after gynecologic surgery. J Minim Invasive Gynecol. 2014;21(1):64–67.

7. Joseph WJ, Sinno S, Brownstone ND, et al. Creating the perfect umbilicus: a systematic review of recent literature. Aesthetic Plast Surg. 2016;40(3):372–379.

8. Sisti A, Huayllani MT, Boczar D, et al. Umbilical reconstruction techniques: a literature review. Aesthetic Plast Surg. 2021;45(3):1078–1096.

9. Chen Y, Zheng Y, Xu LF, et al. Zheng's anchor suturing technique for safe and cosmetic umbilical incision in transumbilical laparoendoscopic single-site surgeries. Surg Today. 2023;53(2):274–277.

10. Ren YH, Gan F, Wang JL. Application of the Sturmdorf suture in umbilical reconstruction during transumbilical laparoendoscopic single-site surgery. [Article in Chinese]. China J Endosc. 2023;29(7):79–82.

11. Chang JW, Oh J, Jung US. Umbilical quilting suture technique during single-port laparoscopic surgery. JSLS. 2018;22(1):e2017.00088.

12. Draaijers LJ, Tempelman FR, Botman YA, et al. The patient and observer scar assessment scale: a reliable and feasible tool for scar evaluation in burn patients and staff. Plast Reconstr Surg. 2004;113(7):1960–1965.

13. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. PLoS Med. 2007;4(10):e296.

14. Noh JJ, Kim TH, Kim CJ, et al. Incisional hernia after 2498 single-port access (SPA) gynecologic surgery over a 10-year period. Sci Rep. 2020;10(1):17388.

15. Zhu YP, Liang S, Zhu L, et al. Trocar-site hernia after gynecological laparoscopic surgery: a 20-year, single-center experience. Chin Med J (Engl). 2019;132(22):2677–2683.

16. Gunderson CC, Knight J, Ybanez-Morano J, et al. The risk of umbilical hernia and other complications with laparoendoscopic single-site surgery. J Minim Invasive Gynecol. 2012;19(1):40–45.

17. Alhambra-Rodríguez de Guzmán C, Morandeira-Rivas AJ, Herrero-Bogajo ML, et al. Incidence and risk factors of incisional hernia after single-incision endoscopic surgery. J Laparoendosc Adv Surg Tech A. 2020;30(3):251–255.

18. Hom DB, Davis ME. Reducing risks for poor surgical wound healing. Facial Plast Surg Clin North Am. 2023;31(2):171–181.

19. Ata A, Lee J, Bestle SL, et al. Postoperative hyperglycemia and surgical site infection in general surgery patients. Arch Surg. 2010;145(9):858–864.

20. Avci P, Gupta A, Sadasivam M, et al. Low-level laser (light) therapy (LLLT) in skin: stimulating, healing, restoring. Semin Cutan Med Surg. 2013;32(1):41–52.

21. Pereira DA, Mendes PGJ, de Souza Santos S, et al. Effect of the association of infra-red and red wavelength photobiomodulation therapy on the healing of post-extraction sockets of third lower molars: a split-mouth randomized clinical trial. Lasers Med Sci. 2022;37(5):2479–2487.

Figure legends

Fig. 1 Schematic diagram of the four suture techniques.

Fig. 2 Examples of umbilicoplasty using the four suture techniques. Double figure-of-eight anchoring (A1–A3); single figure-of-eight (B1–B3); double-U anchoring (C1–C3); continuous suturing (D1–D3); postoperative umbilical appearance at one month (E1–E4). No scale bar was included as umbilicus serves as intrinsic reference.

Fig. 3 Decision tree for individualized umbilical reconstruction. The choice of suture technique is guided by the target umbilical shape. Note: for a small umbilical ring, the single figure-of-eight suture (group B) is preferred; for a large ring, anchoring techniques (groups A or C) are more reliable. No scale bar was included as umbilicus serves as intrinsic reference.