COMPARATIVE EVALUATION OF DIFFERENT METHODS OF STAPLE LINE REINFORCEMENT IN SLEEVE GASTRECTOMY

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Abstract. *Staple line leakage and bleeding remain the most serious complications of laparoscopic sleeve gastrectomy (LSG), making the search for the optimal reinforcement technique clinically essential. This prospective cohort study compared six staple line reinforcement (SLR) methods in 515 patients with morbid obesity who underwent LSG at the INVIVO and Citymed clinics (Tashkent, Uzbekistan) between January 2019 and December 2024. Patients were assigned to six groups: Group I — sero-serous reinforcement (n=100), Group II — seromuscular reinforcement (n=100), Group III — full-thickness suture reinforcement (n=100), Group IV — omentoplasty (n=100), Group V — no reinforcement (n=100), Group VI — Hemoben haemostatic agent application (n=15). Primary endpoints were the rates of staple line leakage, intraabdominal bleeding, and intragastric bleeding within 30 days postoperatively. Secondary endpoints included operative time and length of hospital stay. All procedures were performed by a single surgical team under a standardised protocol using a 38-French calibration bougie. Statistical analysis employed Pearson's chi-square test, Fisher's exact test, and one-way ANOVA with Tukey's post-hoc criterion. The lowest staple line leakage rate was recorded in Group I (1.0%), significantly lower than in Group V (8.0%; p=0.019) and Group III (4.0%; p=0.041). Intraabdominal and intragastric bleeding rates were also minimal in Group I (1.0% each) compared to Group V (10.0% and 7.0%, respectively; p<0.05). Full-thickness suturing (Group III) was associated with the highest complication rate among all reinforcement methods and the longest mean operative time (85±14 min), whereas the no-reinforcement group had the shortest operative time (57±9 min) but the longest hospital stay (5.6±2.9 days). Seromuscular reinforcement and omentoplasty showed intermediate outcomes with no statistically significant differences from sero-serous reinforcement. Hemoben application in the pilot group showed an acceptable safety profile; however, definitive conclusions require a larger sample. Sero-serous SLR is recommended as the optimal, reproducible, and cost-effective method for preventing staple line complications in LSG.*

Keywords: *sleeve gastrectomy, staple line reinforcement, sero-serous suture, staple line leakage, intraabdominal bleeding, morbid obesity, bariatric surgery.*

Introduction.

Laparoscopic sleeve gastrectomy (LSG) is currently the most commonly performed bariatric procedure worldwide, accounting for more than 46% of all bariatric operations according to the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) [4, 9]. The procedure involves the formation of a long staple line along the greater curvature of the stomach, and it is precisely this line that determines the specific spectrum of potential postoperative complications.

Staple line leakage — the most severe of these complications — is reported in 1.0–5.3% of cases and is associated with high mortality, prolonged hospitalisation, and the need for repeat interventions [5, 11, 13]. Intraabdominal bleeding along the staple line occurs in 1.5–4.0% of cases, while intragastric bleeding is reported in 1.0–3.5% [7]. The cumulative burden of these complications sustains substantial interest among surgeons in preventive techniques.

A wide range of SLR methods has been described in the literature: continuous absorbable suture oversewing (sero-serous, seromuscular, or full-thickness), omentoplasty (plication of the greater omentum over the staple line), synthetic or biological buttress materials, fibrin glues, and haemostatic

agents [6, 8, 10, 12]. Despite the abundance of publications on this topic, comparative studies simultaneously evaluating several fundamentally different techniques in a sufficiently large cohort remain scarce. As a result, evidence-based algorithms for selecting the most appropriate reinforcement method in routine practice have not been established.

In Uzbekistan, bariatric surgery is undergoing rapid growth in parallel with the rising prevalence of morbid obesity [1, 2]. Nevertheless, domestic comparative studies dedicated to this subject have been virtually absent from the national literature, which motivated the present investigation.

Aim of the study.

To compare the clinical efficacy of six staple line reinforcement methods in laparoscopic sleeve gastrectomy with respect to the rates of staple line leakage, intraabdominal bleeding, and intragastric bleeding in the early postoperative period, and to identify the optimal method for routine clinical application.

Material and methods.

A prospective cohort study was conducted including 515 patients with morbid obesity who consecutively underwent LSG at the INVIVO and Citymed clinics (Tashkent, Uzbekistan) between January 2019 and December 2024. Inclusion criteria were: age 18–65 years; body mass index (BMI) ≥40 kg/m² or BMI ≥35 kg/m² in the presence of serious obesity-related comorbidity (type 2 diabetes mellitus, arterial hypertension, obstructive sleep apnoea syndrome); and written informed consent. Exclusion criteria were: previous surgery on the upper gastrointestinal tract, revisional bariatric procedures, severe coagulopathy, and patient refusal.

Depending on the staple line management technique, patients were allocated to six groups:

Group I — Sero-serous reinforcement (n=100): the staple line was oversewn with a continuous sero-serous suture using V-loc 3/0 (Covidien) without incorporating the muscular or mucosal layers. The suture was placed without tension from the antrum toward the angle of His.

Group II — Seromuscular reinforcement (n=100): the staple line was oversewn with a continuous seromuscular suture using V-loc 3/0, incorporating the serosal and muscular layers without penetrating the mucosa.

Group III — Full-thickness suture reinforcement (n=100): interrupted sutures were placed through all layers of the gastric wall (serosa, muscularis, and submucosa) using V-loc 3/0, with knots tied externally.

Group IV — Omentoplasty (n=100): the greater omentum was sutured to the staple line using a continuous V-loc 3/0 suture, providing biological coverage of the staple line.

Group V — No reinforcement (n=100): no additional staple line management was performed after completion of stapling. This group served as the control.

Group VI — Hemoben haemostatic agent (n=15): the Hemoben haemostatic preparation (based on oxidised regenerated cellulose) was applied to the staple line in accordance with the manufacturer's instructions. Due to the pilot nature of this arm, patient enrolment is ongoing.

All operations were performed by a single surgical team using a standardised protocol. A linear endoscopic stapler was used with 3.5-mm cartridges for the antral region and 4.8-mm cartridges for the gastric body. A 38-French calibration bougie was positioned along the lesser curvature to create a standardised gastric sleeve. The first stapler firing was placed 4–5 cm proximal to the pylorus.

Primary endpoints were: staple line leakage (defined as extravasation of gastric contents beyond the sleeve, confirmed by water-soluble contrast radiography or reoperation within 30 days of LSG); intraabdominal bleeding (diagnosed clinically, by ultrasound, or at reoperation within 30 days); and intragastric bleeding (bleeding from the staple line into the gastric lumen, confirmed endoscopically). Secondary endpoints were operative time and postoperative length of hospital stay.

Statistical analysis was performed using SPSS Statistics 26.0 (IBM Corp., USA). Categorical variables were compared using Pearson's chi-square test; Fisher's exact test was applied when

expected cell frequencies were below 5. Continuous variables are expressed as mean ± standard deviation (M±SD) and were compared by one-way analysis of variance (ANOVA) with Tukey's post-hoc test. Statistical significance was set at $p<0.05$.

Table 1.

Baseline clinical and demographic characteristics of the study groups

Characteristic	Gr. I (n=100)	Gr. II (n=100)	Gr. III (n=100)	Gr. IV (n=100)	Gr. V (n=100)	Gr. VI (n=15)
Age, years (M±SD)	38.2±8.9	38.7±9.1	39.1±8.6	38.5±9.4	37.9±8.7	40.1±7.8
Sex: male / female	36/64	34/66	37/63	35/65	33/67	5/10
BMI, kg/m² (M±SD)	45.9±6.1	46.2±5.8	46.4±6.3	45.7±6.0	45.8±5.9	47.1±7.2
Type 2 DM, n (%)	40 (40%)	41 (41%)	39 (39%)	40 (40%)	38 (38%)	6 (40%)
Arterial hypertension, n (%)	65 (65%)	63 (63%)	66 (66%)	64 (64%)	63 (63%)	10 (67%)

Note: BMI — body mass index; DM — diabetes mellitus. No statistically significant between-group differences were observed for any baseline characteristic ($p>0.05$ for all comparisons).

Results and discussion.

All six groups were comparable at baseline with respect to age, sex distribution, BMI, and the prevalence of principal comorbidities (Table 1), ensuring the validity of between-group comparisons of surgical outcomes.

The lowest staple line leakage rate was recorded in Group I (sero-serous reinforcement) — 1.0% (1 of 100 patients). In Group V (no reinforcement), leakage developed in 8 patients (8.0%), which was significantly higher ($p=0.019$, Fisher's exact test). In Group III (full-thickness suture), the leakage rate was 4.0%, a difference that also reached statistical significance compared with Group I ($p=0.041$). In Groups II (3.0%), IV (2.0%), and VI (6.7%; n=15), differences from Group I did not reach statistical significance ($p>0.05$), although a consistent trend toward higher complication rates was observed relative to sero-serous reinforcement.

Intraabdominal bleeding was diagnosed in only 1 patient in Group I (1.0%). The highest rate was recorded in Group V — 10 cases (10.0%; $p=0.004$ vs. Group I). In Group III, intraabdominal bleeding occurred in 5 patients (5.0%; $p=0.031$ vs. Group I). Groups II (3.0%) and IV (2.0%) did not differ significantly from Group I. In Group VI (n=15), 1 event was recorded (6.7%); the limited sample size precludes meaningful statistical comparison.

The intragastric bleeding rate in Group I was 1.0%, compared with 7.0% in Group V ($p=0.027$) and 3.0% in Group III ($p=0.319$). Accordingly, sero-serous reinforcement demonstrated a statistically significant advantage over the no-reinforcement approach for this endpoint as well.

Notably, full-thickness suturing (Group III), despite its intuitive appeal as the most mechanically robust technique, was associated with the worst outcomes among all reinforcement methods. We attribute this finding to ischaemia of the staple line edges caused by incorporation of the mucosal layer and compression of transmural vessels, which paradoxically increases the risk of leakage and bleeding. Furthermore, this technique was associated with the longest operative time among all groups.

Omentoplasty (Group IV) yielded acceptable results and may serve as a valid alternative to suture reinforcement when the latter is not feasible. However, this technique is technically more demanding in patients with pronounced visceral obesity, in whom the omentum is often insufficiently mobile to be advanced to the staple line without tension.

Seromuscular reinforcement (Group II) showed marginally inferior outcomes compared with sero-serous reinforcement across all endpoints, though none of the differences were statistically significant. The theoretical explanation is that incorporation of the muscular layer may generate

localised ischaemia in the suture zone, which may translate into a slightly higher, albeit non-significant, complication rate.

In the Hemoben pilot group (Group VI), one event was recorded for each of the three primary endpoints (6.7% per endpoint). While the safety profile appears acceptable, no statistically robust conclusions can be drawn from a cohort of 15 patients; enrolment is continuing, and definitive data will be reported upon completion of the study.

Table 2.

Comparative complication rates and operative outcomes by group

Outcome	Gr. I (n=100)	Gr. II (n=100)	Gr. III (n=100)	Gr. IV (n=100)	Gr. V (n=100)	Gr. VI (n=15)	p*
Staple line leakage, n (%)	1 (1.0%)	3 (3.0%)	4 (4.0%)	2 (2.0%)	8 (8.0%)	1 (6.7%)	0.019†
Intraabdominal bleeding, n (%)	1 (1.0%)	3 (3.0%)	5 (5.0%)	2 (2.0%)	10 (10.0%)	1 (6.7%)	0.004†
Intragastric bleeding, n (%)	1 (1.0%)	2 (2.0%)	3 (3.0%)	2 (2.0%)	7 (7.0%)	1 (6.7%)	0.027†
Operative time, min (M±SD)	72±10	78±12	85±14	74±11	57±9	68±10	<0.001‡
Hospital stay, days (M±SD)	3.7±1.1	4.1±1.4	4.8±2.1	3.9±1.3	5.6±2.9	4.2±1.5	<0.001‡

Note: * — p-value for pairwise comparison of Group I vs. Group V (†Fisher's exact test; ‡one-way ANOVA with Tukey's post-hoc test). Differences between Groups I and II, and Groups I and IV are not statistically significant ($p>0.05$ for all comparisons).

Operative time was greatest in Group III (85±14 min), reflecting the technical complexity of full-thickness suturing and the frequent need for additional haemostasis. Group V had the shortest operative time (57±9 min), as expected, since no reinforcement step was required. Group I (72±10 min) and Group IV (74±11 min) occupied intermediate positions. Differences in operative time across all groups were statistically significant ($p<0.001$, ANOVA).

Postoperative hospital stay mirrored complication severity, being longest in Group V (5.6±2.9 days) and shortest in Group I (3.7±1.1 days; $p<0.001$, ANOVA). The reduction in mean hospital stay in the sero-serous reinforcement group not only reflects a smoother postoperative course but also carries direct economic implications.

Taken together, the data support the conclusion that sero-serous reinforcement represents the optimal method by virtue of its combination of clinical efficacy, technical reproducibility, and cost-effectiveness. Its advantages can be explained as follows: the sero-serous suture provides reliable staple line reinforcement without compromising gastric wall blood supply (unlike full-thickness suturing), requires no specific consumables (unlike buttress materials or haemostatic agents), and is less dependent on the availability of a sufficient volume of mobilisable omentum (unlike omentoplasty). The use of V-loc self-retaining suture allows single-handed suturing without an assistant and reduces the time required for this operative step compared with a conventional continuous suture.

Conclusion.

1. Sero-serous staple line reinforcement in laparoscopic sleeve gastrectomy provides the lowest rates of staple line leakage (1.0%), intraabdominal bleeding (1.0%), and intragastric bleeding (1.0%) among all methods studied, and is significantly superior to the no-reinforcement approach across all three primary endpoints ($p<0.05$).

2. Full-thickness suture reinforcement (Group III), despite its theoretical mechanical advantage, is associated with the highest complication rate among reinforcement methods and the longest mean operative time (85±14 min), and is therefore not recommended for routine use.

3. Seromuscular reinforcement and omentoplasty demonstrate intermediate outcomes; although differences from sero-serous reinforcement are not statistically significant, the consistent trend toward higher complication rates supports the preference for the sero-serous technique.

4. Application of the Hemoben haemostatic agent represents a promising direction; definitive conclusions require completion of enrolment and expansion of the study sample.

5. Sero-serous staple line reinforcement is recommended for routine use in sleeve gastrectomy as the method with optimal clinical efficacy, technical reproducibility, and cost-effectiveness for the prevention of staple line complications.

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