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Assessing the Learning Curve of Linear and Wedge Labiaplasty Using the Cumulative Summation (CUSUM) Test

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ABSTRACT

Purpose: To assess and compare the learning curves of linear and wedge labiaplasty performed by trainees with no prior cosmetic gynecology experience using the Learning Curve-Cumulative Summation (LC-CUSUM) method.

Methods: This retrospective study analyzed the first 40 consecutive cases performed by two obstetrician-gynecologist trainees. Trainee 1 performed linear labiaplasty, and Trainee 2 performed wedge labiaplasty. Both trainees had completed a structured two-day training course. Unfavorable outcomes were defined as wound dehiscence, postoperative infection requiring antibiotics, or esthetic dissatisfaction where both surgeon and the patient agree on a revision. The acceptable failure rate (p_0) was set at 3% and the unacceptable rate (p_1) at 10%, with $\alpha=0.05$ and $\beta=0.20$. LC-CUSUM curves were constructed using standard algorithms to identify the point at which each trainee achieved competence (decision limit $h=2.5$).

Results: Patient demographics did not differ significantly between the two groups. Operative time was significantly longer for wedge labiaplasty (98±20 min) compared with linear labiaplasty (74±22 min, $p<0.01$). The overall unfavorable outcome rate was 2.5% for linear and 12.5% for wedge labiaplasty ($p=0.08$). LC-CUSUM analysis indicated that competence was achieved after the eighth case for linear labiaplasty and the thiteenth case for wedge labiaplasty. Both trainees' performance curves remained below the decision limit, suggesting acceptable performance after these thresholds were reached.

Conclusion: The LC-CUSUM test demonstrated that linear labiaplasty requires a shorter learning curve compared with wedge labiaplasty in trainees new to cosmetic gynecology. The wedge technique, while esthetically advantageous, is technically more demanding and associated with a higher early complication rate and longer operative time. These results provide evidence-based guidance for training programs, suggesting that linear labiaplasty should be introduced first in structured cosmetic gynecology curricula. Adoption of LC-CUSUM-based monitoring may enhance patient safety and standardize competence assessment in aesthetic gynecologic surgery.

Keywords: Learning curve, cumulative sum, labiaplasty, cosmetic gynecology, surgical education

INTRODUCTION

Cosmetic gynecologic surgery, particularly labia minora plasty (LMP), has seen a substantial increase in demand globally over the past two decades.[1,2] As the prevalence of these procedures rises, so too does the necessity for structured, objective training protocols to ensure optimal outcomes and patient safety.[3] LMP is considered an esthetic procedure requiring technical precision, a clear understanding of vulvar anatomy, and advanced surgical judgment to achieve satisfactory functional and cosmetic results.[4] Due to high patient expectations and the potential for complications, including wound dehiscence, infection and esthetic dissatisfaction, acquisition of competence by a trainee surgeon should be carefully assessed.[5,6]

The traditional assessment of surgical skill acquisition, which often relies on expert opinion, case volume, or simple complication rates, lacks the statistical rigor needed for modern surgical education.[7] The Learning Curve Cumulative Summation (LC-CUSUM) test provides a powerful, graphical,

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and sequential statistical method for objectively monitoring a trainee's performance and determining the point at which they achieve a predefined standard of competence.[8] Unlike traditional control charts, the LC-CUSUM method is specifically designed to detect sustained shifts in performance metrics and is ideally suited for tracking the learning process in new procedures.[9]

The aim of this study was to apply the LC-CUSUM test to the initial experience of surgical trainees learning two distinct LMP techniques: linear and wedge labiaplasty. By comparing the case volume required for each trainee to reach a predefined level of competence, it was hoped to provide evidence of the relative trajectories of the learning curves of these two common procedures.

METHODS

This retrospective study analyzed the first 40 consecutive cases performed by two obstetrician-gynecologist trainees. Trainee 1 performed linear labiaplasty, and Trainee 2 performed wedge labiaplasty. Both trainees had completed a structured two-day training course. Unfavorable outcomes were defined as wound dehiscence, postoperative infection requiring antibiotics, or esthetic dissatisfaction where both surgeon and the patient agree on a revision. The acceptable failure rate (p_0) was set at 3% and the unacceptable rate (p_1) at 10%, with α=0.05 and β=0.20. LC-CUSUM curves were constructed using standard algorithms to identify the point at which each trainee achieved competence (decision limit h=2.5).

Study Design and Participants

This was a retrospective review of the first 40 consecutive cases performed by two trainee gynecologic surgeons, one performing linear labiaplasty and the other performing wedge labiaplasty. Both trainees were specialists in Obstetrics and Gynecology who had never previously performed cosmetic gynecology procedures, including LMP. The study was conducted two years after the trainees had completed their initial training course. Both trainees provided informed consent for the retrospective use of their de-identified patient data.

Prior to initiating practice, each trainee attended a two-day hands-on live surgery course. On the first day, the participants received four hours of theoretical instruction covering vulvar and lower abdominal anatomy, patient selection, informed consent, and operative techniques for LMP. This was followed by two hours of video demonstrations of multiple techniques, including technical tips and troubleshooting. On the second day, each trainee performed and assisted in four live LMP procedures under expert supervision.

After the course, the trainees returned to their respective clinics and began performing cosmetic gynecological procedures. Their initial cases were reviewed by the same expert surgeon with over 15 years of experience in cosmetic gynecology. Two years after the course, the trainees were contacted and invited to participate in this study. Both agreed to share data from their first 40 consecutive LMP cases each. Ethical approval was obtained from the Tekirdağ Namık Kemal University of Ethics Committee (approval number: 2025.140.07.10, date: 29.07.2025).

Patient Selection and Surgical Techniques

All patients underwent LMP primarily for cosmetic reasons. Labium minus classification was performed based on the degree of protrusion exceeding the labia majora and morphological variations, as previously described.[10] Linear labiaplasty was performed with the patient in the lithotomy position. After surgical preparation, the portion of the labium minus protruding beyond the labia majora was excised, ensuring that a minimum of 1 cm of labium minus tissue remained. Excision was performed using curved scissors or a blade. Hemostasis was achieved using needle-tip electrocautery at 35 watts in spray mode. The labial edges were then approximated using 4.0 or 5.0 rapid absorbable sutures in a continuous or interrupted fashion.[11] Wedge labiaplasty involved a V-shaped excision of the most protuberant portion of the labium minus. The size of the resected wedge depended on the individual patient's anatomy. Resection was planned posterior to the central labial artery, which was identified using a previously described transillumination technique.[12] The technique included either central or inferior wedge resections based on anatomical requirements.[13,14] Postoperative care included hourly 10-minute ice packs, non-steroidal anti-inflammatory drugs, and cephalosporin antibiotic prophylaxis. Patients were advised to abstain from sexual intercourse for four weeks postoperatively. Follow-up included evaluations at one and six months post-operation, including clinical review and photographic assessment.

Outcome Measures and Learning Curve Cumulative Summation Parameters

Unfavorable outcomes (failure) were defined as any of the following occurrences requiring intervention: wound dehiscence; labial infection requiring antibiotics; or patient esthetic dissatisfaction requiring a revision surgery.

Statistical Analysis

Based on a previous study showing a 2.7% complication rate in similar cosmetic genital procedures (72/2597), the acceptable failure rate was set at 3% (p_0=0.03) and the unacceptable failure rate at 10% (p_1=0.10).[15] Type 1 error (α) which is the probability of falsely declaring competence was set at 0.05, and type II error (β) which is probability of falsely rejecting a trainee's competence was set at 0.20. From published LC-CUSUM formulas, the sample weight for success (x=0) was 0.0080043 and for failure (x=1) was -1.38629. The average run length under null hypothesis (ARL_0) was set at 40, representing the expected number of cases before a trainee of acceptable competence (p_0) is falsely declared incompetent (a type I error), with a decision interval (h) of 2.5, which is an established value used in the literature, which corresponds to the defined (ARL_0) of 40 for detecting deviations from the acceptable performance standard.[16-19] The learning curve was considered complete when the LC-CUSUM score dropped back to zero and remained below the decision interval for a sustained period, indicating that an acceptable p_0 had been achieved. Continuous variables were

compared using independent samples t-tests. Categorical variables were compared using the chi-square test or Fisher's exact test where appropriate. Analysis of variance was used to compare continuous variables between operators as two operators were used in this study. Statistical significance was set at $p<0.05$. The statistical analysis for LC-CUSUM was performed using established methods.

RESULTS

The first 40 consecutive cases for each trainee were analyzed (Table 1). Baseline patient demographic characteristics did not differ between the two groups. There was no difference between intervention characteristics with the exception of a significantly longer operative time for wedge labiaplasty (74±22 min vs. 98±20 min, $p<0.01$). The failure rate for Trainee 1 (linear labiaplasty) was 2.5%, while it was 12.5% for Trainee 2 (wedge labiaplasty). Although the difference in the overall unfavorable outcome was not significant ($p=0.08$), the rate was four-fold higher for the wedge technique. Specific adverse events for Trainee 2 included three cases of wound dehiscence and two cases of patient cosmetic dissatisfaction. LC-CUSUM analysis demonstrated that competency was achieved after the eighth procedure for Trainee 1 (Figure 1) and after the thirteenth procedure for Trainee 2 (Figure 2). The maximum LC-CUSUM score reached was 0.5 for Trainee 1 and 1.2 for Trainee 2, remaining well below the decision limit (h=2.5) in both cases, suggesting that the predefined level of unacceptable failure was avoided early in the learning process.

Table 1. Comparison of patient demographic and intervention characteristics for the two surgical techniques

	Trainee 1 - linear labiaplasty (n=40)	Trainee 2 - wedge labiaplasty (n=40)	*p*
Age (years)	29.4±9.2	30.5±8.8	0.50
BMI (kg/m²)	27.5±2.3	28.1±3.2	0.30
Labia minora type 1	12 (30%)	9 (22.5%)	0.50
Labia minora type 2	21 (52.5%)	26 (65%)	0.50
Labia minora type 3	7 (17.5%)	5 (12.5%)	0.50
Operation time (min)	74±22	98±20	<0.01
Overall unfavorable outcome	1 (2.5%)	5 (12.5%)	0.08
Wound dehiscence	0	3 (7.5%)	0.07
Infection	1 (2.5%)	2 (5%)	0.50
Aesthetic dissatisfaction	0	2 (5%)	0.10

BMI: Body mass index

DISCUSSION

In this study, the LC-CUSUM test was used to evaluate the acquisition of competency in two different LMP techniques performed by two trainees with no prior experience in cosmetic gynecology. Our findings demonstrated that competency was achieved after eight and 13 procedures for the linear and wedge techniques respectively. To the best of our knowledge, this is one of the first reports applying LC-CUSUM to cosmetic genital surgery and provides quantitative data on the possible number of cases required to reach an acceptable performance level for each technique.

The LC-CUSUM method has been increasingly used to objectively assess the progression of surgical proficiency in various fields, including hysteroscopy, laparoscopy, and ultrasound-guided procedures. For example, in outpatient hysteroscopy, a third-year trainee was reported to require approximately 56 procedures to reach an acceptable performance threshold.[19] Similarly, in deep infiltrating endometriosis mapping using ultrasonography, the number of cases required to achieve competence ranged from 17 to 44, depending on the lesion location.[20] In pelvic reconstructive surgery, learning curves often extend to 30-50 procedures depending on mesh use before proficiency is reached.[21] Compared with these examples, the present results suggest that LMP may have a relatively shorter learning curve, particularly for the linear technique.

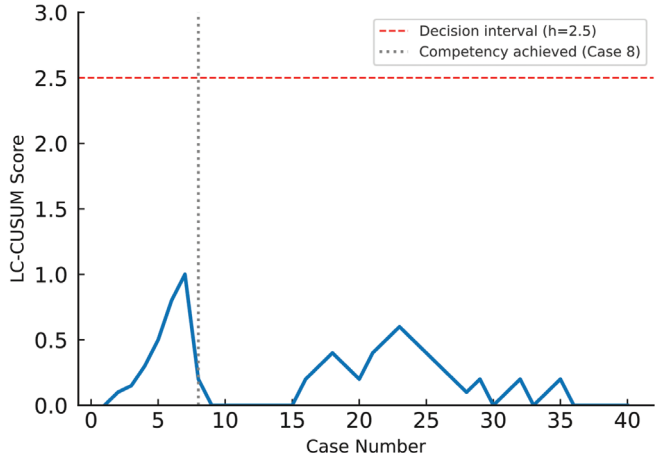

Figure 1. LC-CUSUM Learning Curve - Trainee 1 (linear labiaplasty)
LC-CUSUM: Learning Curve-Cumulative Summation

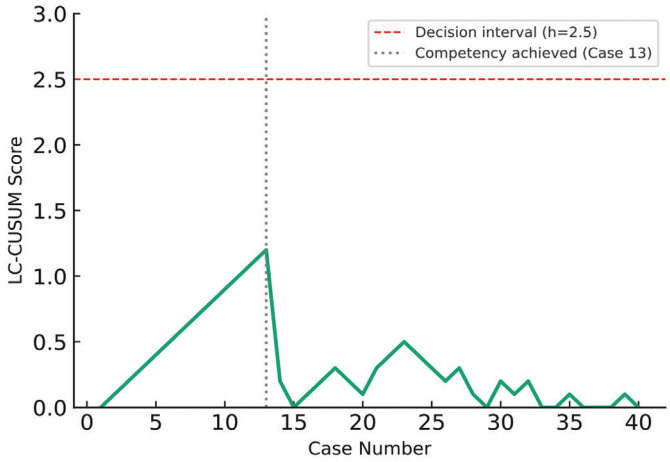

Figure 2. LC-CUSUM Learning Curve - Trainee 2 (wedge labiaplasty)
LC-CUSUM: Learning Curve-Cumulative Summation

The longer operative time and higher failure rate observed for wedge labioplasty in this study are consistent with prior evidence indicating that the wedge method, although esthetically advantageous, is associated with a greater technical challenge. A recent meta-analysis reported that wedge resection was associated with a slightly higher risk of wound dehiscense (3-5%) than edge or linear excision methods.[5] Our findings align with this pattern, showing a 12.5% unfavorable outcome rate for wedge procedures compared with 2.5% for linear resections. This observation highlights the technical complexity of wedge labioplasty and suggests that it may require a longer training phase to achieve similar levels of safety and efficiency. The fact that Trainee 2 eventually met this standard after 13 cases, as evidenced by the LC-CUSUM score returning to the acceptable range, suggested eventual attainment of proficiency for this the procedure with supervision. The eight case requirement for linear labiaplasty was remarkably short, which may indicate this technique as more suited as an entry-level procedure for trainees in cosmetic gynecology. For both trainees, the maximum LC-CUSUM values remained well below the decision interval for unacceptable performance, suggesting that the initial structured training was effective in preventing catastrophic failures early in the learning process, highlighting the importance of structured preparatory training for minimizing patient risks during the initial learning phase.

Study Limitations

This study has several limitations. The small number of trainees is the primary limitation, which restricts the generalizability of our findings. We acknowledge that individual differences in inherent dexterity, prior surgical exposure or learning style could significantly influence the apparent rate of skill acquisition, potentially reflecting personal aptitude rather than technique superiority. However, this study serves as a pilot comparison to provide objective, quantitative data on the learning curve length where previous evidence was lacking. The retrospective design is also a limitation. While the LC-CUSUM method is optimally used in a prospective manner to provide real-time feedback and monitor the acquisition of competence, its retrospective application remains a valid tool for auditing outcomes. Moreover, the definition of failure should be standardized in future studies; including both minor cosmetic dissatisfaction and major complications under the same category may overestimate the failure rate. Patient satisfaction was assessed from clinical documentation and photographic evaluation rather than through a validated scoring system, which may limit the interpretability and comparability of subjective esthetic outcomes. The follow-up period of six months may also be insufficient to capture late complications or patient-perceived outcomes, such as scar satisfaction and sexual function. Furthermore, patient selection bias cannot be excluded, as early cases may have involved less challenging anatomy, potentially accelerating early competence attainment. Lastly, differences in institutional resources or postoperative care could influence outcomes and should be considered in multicenter studies.

Future studies should expand on this work by including a larger number of trainees who perform both techniques, across multiple centers to capture variability in working environments. Incorporating risk-adjusted LC-CUSUM models could allow for the weighting of case complexity, thereby providing more personalized assessments of learning progression. Moreover, integrating patient-reported outcomes such as pain, sexual satisfaction and body image perception would offer a more comprehensive evaluation of surgical competency beyond complication rates alone. Simulation-based training and cadaveric practice should also be explored as tools to accelerate skill acquisition before live patient cases.

CONCLUSION

The application of the LC-CUSUM test to LMP demonstrates that the linear technique may have a significantly shorter learning curve, compared to the more technically demanding wedge resection technique. This study provides objective data to support the strategic planning of surgical training in cosmetic gynecology, suggesting that the linear technique

may be prioritized early in a trainee's experience. Formal training protocols using the LC-CUSUM method may help to objectively define and monitor the achievement of surgical competence, thereby ensuring patient safety and standardized outcomes.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Tekirdağ Namık Kemal University of Ethics Committee (approval number: 2025.140.07.10, date: 29.07.2025).

Informed Consent: Both trainees provided informed consent for the retrospective use of their de-identified patient data.

Footnotes

Authorship Contributions

Surgical and Medical Practices: E.H.C., G.A., Concept: B.Ü., Design: B.Ü., Data Collection or Processing: E.H.C., G.A., Analysis or Interpretation: B.Ü., Literature Search: B.Ü., Writing: B.Ü.

Conflict of Interest: No conflict of interest was declared by the authors.

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