



RESEARCH ARTICLE

Learning Curve Analysis of Pelvic Organ Prolapse Surgery Among Urogynecology and Aesthetic Reconstruction Trainees

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Abstract

Background: Pelvic organ prolapse (POP) is a condition in which pelvic organs descend into the vaginal canal due to weakened muscles and tissues. It represents a significant global health burden with a worldwide prevalence of 30.9% and 26.4% in Jakarta. As the female life expectancy in Indonesia continues to rise, the prevalence of POP estimated to increase by 40%, further affecting women's quality of life. The need for POP surgery is projected to reach 48.1% by 2050. Given the complexity of POP reconstruction, adequate training and evaluation of urogynecology subspecialists are essential to ensure patient safety and optimal outcomes.

Objective: To analyze the learning curve of POP surgeries performed by urogynecology subspecialty trainees at RSCM using the Cumulative Sum (CUSUM) method in order to evaluate surgical skill development and optimize clinical training quality.

Methods: This study applied a CUSUM learning curve analysis to assess the performance of three subspecialty trainees during ten POP reconstructive surgeries. Variables analyzed included operation duration and intraoperative blood loss.

Result: CUSUM analysis is able to identify the point at which trainees achieve procedural competence and stable performance, reflected by plateau phase in operation time and reduced intraoperative bleeding. This method allows for early detection of learning challenges and facilitates timely corrective actions during training.

Conclusion : CUSUM learning curve analysis provides a sensitive and continuous assessment tool for monitoring surgical competency of urogynecology subspecialty trainees. This approach in clinical training can enhance the standardization of education, improve patient safety, and optimize clinical outcomes in POP management.

Keywords: pelvic organ prolapse (POP), learning curve, cumulative sum (CUSUM), urogynecology training, surgical competency, clinical education

INTRODUCTION

Pelvic organ prolapse (POP) is a condition characterized by the weakening of the pelvic floor muscles and supporting connective tissues, resulting in the descent of one or more pelvic organs into or beyond the vaginal canal. This disorder represents a significant global health burden among women, with a reported worldwide prevalence of approximately 30.9% and a national prevalence in Indonesia of 26.4% as of 2016. As life expectancy among Indonesian women continues to rise, the prevalence of POP is projected to increase by approximately 40% with every additional decade of age, leading to a substantial decline in quality of life and increased demand for surgical management.

Surgical intervention remains as definitive treatment for symptomatic POP, with the estimated rate of surgical procedures expected to reach 48.1% by 2050. This highlights the critical importance of surgical proficiency and continuous competency evaluation in the management of pelvic floor disorders. Among the various surgical techniques for POP, vaginal hysterectomy (TVH) is the most commonly performed procedure by urogynecologists, accounting for nearly 60% of POP surgeries, often combined with anterior or posterior colporrhaphy (32%). The high surgical volume underscores the need for standardized training and assessment systems to ensure adequate skill acquisition among subspecialty trainees in urogynecology and reconstructive pelvic surgery. The Royal Australian College of Obstetricians and Gynaecologists (RACOG) recommends the presence of one urogynecologist per 500,000 population as an optimal ratio for ensuring quality pelvic health services. To meet this demand, Indonesia has established three national subspecialty training centers. However, the rapid expansion of training programs introduces challenges in maintaining consistent and standardized medical education quality. Given the high prevalence of procedures such as TVH, anterior colporrhaphy (KA), and posterior colporrhaphy (KPR), these surgeries serve as suitable standardized indicators for evaluating surgical competence among trainees.

Surgical performance can be objectively monitored through learning curve analysis, which assesses the progression of technical proficiency over time and procedural repetition. Learning curve analysis in surgery can be categorized into four principal methods: graphical inspection, split-group analysis, cumulative sum (CUSUM) analysis, and regression-based modeling. Among these, CUSUM analysis is considered one of the most robust and sensitive methods for continuous performance monitoring. It enables early detection of performance deviations, quantifies improvement trends, and facilitates timely corrective actions during the learning process.

The increasing burden of POP due to population aging and prolonged female life expectancy presents a dual challenge: ensuring optimal surgical outcomes for patients while maintaining structured and evidence-based training for subspecialty physicians. At Dr. Cipto Mangunkusumo National General Hospital (RSCM) Jakarta, the national referral center for urogynecology in Indonesia, there is an institutional obligation to ensure that subspecialty trainees achieve adequate competency levels in reconstructive pelvic surgery. By monitoring variables such as operative duration and intraoperative blood loss, it provides insight into the rate and consistency of surgical skill acquisition. Furthermore, it allows educators to identify specific points in the learning process

where significant improvement occurs, as well as stages that require additional supervision or educational interventions. Such evidence-based assessment tools are essential for ensuring patient safety, optimizing training efficiency, and supporting data-informed educational reforms.

This study seeks to analyze the learning curve of subspecialty trainees in urogynecology at RSCM by applying CUSUM analysis based on two key operative parameters: operative duration and intraoperative blood loss. The specific research questions include finding whether the demographic and clinical characteristics of urogynecology subspecialty trainees at RSCM as reflected in their CUSUM curves, studies whether CUSUM analysis of operative duration or intraoperative blood loss will be reflected on the learning curve, and whether we will find improvement trajectory of trainees via CUSUM curve analysis.

METHODS

This study employed a longitudinal descriptive observational design using prospectively collected data from pelvic organ prolapse (POP) reconstructive procedures performed by third semester subspecialty trainees in urogynecology and aesthetic reconstructive surgery at Dr. Cipto Mangunkusumo National General Hospital (RSCM), Jakarta. The study was conducted between January and June 2025, corresponding to the trainees' third semester or until completion of the Direct Observation of Procedural Skills (DOPS) examination. The target population consisted of all third-semester trainees actively performing POP reconstructive surgeries, specifically vaginal hysterectomy with anterior colporrhaphy and colpoperineorrhaphy. Eligible participants were obstetrics and gynecology specialists enrolled in the urogynecology and reconstructive aesthetic program, actively practicing at RSCM, and who consented to continuous performance monitoring through CUSUM analysis. Exclusion criteria included trainees on academic leave, those not actively engaged in surgical procedures during the study period, or those with incomplete operative data. Sampling was conducted purposively, including all eligible trainees meeting the inclusion criteria.

Baseline demographic and clinical data of the trainees were obtained from academic records, while patient characteristics and operative outcomes were extracted from surgical reports and medical records. Benchmark data were established using historical POP surgery records from RSCM. Operative parameters such as duration of surgery and intraoperative blood loss, were analyzed using Statistical Product and Service Solutions (SPSS) version 26.0. Cumulative Sum (CUSUM) analysis was applied following the method of Wu et al. (2022) to evaluate performance trends and learning progression.¹ Acceptable and unacceptable failure rates were defined as $P_0 = 10\%$ and $P_1 = 20\%$, respectively, with α and β error rates set at 0.10. The CUSUM curve plotted cumulative deviations across consecutive procedures, identifying phases of improvement, stabilization, or decline in performance. Ethical approval was obtained from the Health Research Ethics Committee, Faculty of Medicine, Universitas Indonesia, and written informed consent was secured from all participants in accordance with national research ethics guidelines.

RESULT

Participant Characteristics

Three third-semester subspecialty trainees in Urogynecology and Aesthetic Reconstructive Surgery participated in this study. Participant A was a 38 year old male obstetrician-gynecologist with five years of clinical experience and prior exposure to five pelvic organ prolapse (POP) surgeries. Participant B was a 43 year old female with ten years of clinical experience and two prior POP procedures, while Participant C was a 36 year old female with five years of experience and five previous POP operations. All participants had completed one year of subspecialty training at the time of study initiation and had not yet undertaken the Direct Observation of Procedural Skills (DOPS) examination. During the study period (January until July 2025), a total of 108 urogynecologic surgeries were performed, of which 60 were POP reconstructive procedures. Thirty surgeries conducted by the three study participants were included for analysis, while those performed by consultants or visiting fellows were excluded.

Patient Characteristics

The mean age of surgical patients was 63.3 ± 9.6 years, with a mean body mass index (BMI) of 24.7 ± 4.3 kg/m². The majority of patients were overweight or obese (66.7%) and within the 61 until 90 year age group (60%). Most patients were multiparous (60%) or grand multiparous (33.3%), and over half (56.7%) presented with comorbid conditions. POP stage distribution was dominated by stage IV (56.7%), followed by stage III (43.3%), with no stage I–II cases. There were no statistically significant differences among the three trainees' patient groups in terms of age, BMI, parity, comorbidities, or POP stage (all $p > 0.05$), indicating homogeneity in surgical case complexity. Patients characteristic will be shown in appendix (Table 1).

Table 1. Baseline Characteristic

characteristic	Mean	Trainee A (n=10)	Trainee B (n=10)	Trainee C (n=10)	Nilai p
Age	63,33 ± 9,62	65,0 ± 10,6	63,1 ± 8,0	62,0 ± 11,4	0,806 _a
Body Mass index (kg/m ²)	24,73 ± 4,27	24,9 ± 4,5	26,0 ± 5,0	23,0 ± 3,5	0,407 _a
Nutritional state, n (%)					
Body weight less	10 (33,3)	4 (40)	3 (30)	1 (10)	0.095 _b
Body weight over	20 (66,7)	6 (60)	7 (70)	9 (90)	
Age group, n (%)					
41 – 60 years	12 (40)	5 (50)	3 (30)	4 (40)	0.670 _b
61 – 90 years	18 (60)	5 (50)	7 (70)	6 (60)	
Parity, n (%)					
Nulipara –	2 (6,7)	2 (20)	0	0	0.678 _b
Primipara					
Multipara	18 (60)	5 (50)	7 (70)	5 (50)	
Grande multipara	10 (33,3)	3 (30)	3 (30)	5 (50)	
comorbid, n (%)					
With comorbid	17 (56,7)	6 (60)	7 (70)	4 (40)	0.478 _b
Without comorbid	13 (43,3)	4 (40)	3 (30)	6 (60)	
Stage ofPOP, n (%)					
I-II	0 (0)	0	0	0	0.449 _b
III	13 (43,3)	5 (50)	5 (50)	3 (30)	
IV	17 (56,7)	5 (50)	5 (50)	7 (70)	
Stress urine incontinentia, n (%)					
With SUI	10 (33)	2 (20)	5 (50)	3 (30)	0.435 _b
Without SUI	20 (66)	8 (80)	5 (50)	7 (70)	
Elongation cervical, n (%)					
With Elongation	3 (10)	1 (10)	1 (10)	1 (10)	1,000 _b
Without Elongation	27 (90)	9 (90)	9 (90)	9 (90)	
Ballooning, n (%)					
With Ballooning	22 (73)	7 (70)	6 (60)	9 (90)	0.247 _b
Without Ballooning	8 (27)	3 (30)	4 (40)	1 (10)	

Operative Outcomes

Each trainee performed ten POP reconstructive surgeries, comprising total vaginal hysterectomy (TVH), anterior colporrhaphy (KA), and colpoperineorrhaphy (KPR). Participant A performed eight combined TVH, KA, KPR procedures and two other are limited to KA-KPR, while Participants B and C each performed ten complete sets of the three procedures. The median operative duration for TVH was 65 minutes for Participant B, 62.5 minutes for Participant C, and 55.5 minutes for Participant A ($p = 0.579$). For KA, the durations were 45 minutes (C), 42.5 minutes (A), and 25 minutes (B) ($p = 0.061$). For KPR, durations were 46 minutes (C), 35 minutes (A), and 29.5 minutes (B) ($p = 0.452$). The total operative time ranged from 90 to 342 minutes, with the longest recorded in Participant C's group, though differences were not statistically significant ($p = 0.244$). No intraoperative or postoperative complications were reported. Estimated intraoperative blood loss ranged from 20–250 mL, with median losses of 125 mL (A), 100 mL (B), and 100 mL (C) ($p = 0.725$). Median postoperative hospitalization duration was four days in all groups ($p = 0.748$). Operative outcomes data will be shown in appendix (Table 2).

Table 2. Operative Outcomes

Characteristic	Trainee A (n=10)	Trainee B (n=10)	Trainee C (n=10)	Nilai P
Procedure POP				
TVH	8 (26,7)	10 (33,3)	10 (33,3)	0,918 ^b
KA	10 (33,3)	10 (33,3)	10 (33,3)	
KPR	10 (33,3)	10 (33,3)	10 (33,3)	
Total	30	30	30	-
Time operation (minute)				
TVH	55,5 (15–90)	65,0 (15–98)	62,5 (20–162)	0,579 ^b
KA	42,5 (19–60)	25 (15–45)	45,0 (15–80)	0,061 ^b
KPR	35,0 (16–81)	29,5 (15–74)	46,0 (18–100)	0,452 ^b
Total	123,5 (60–203)	127,0 (49–180)	150,0 (90–342)	0,244 ^b
Ccomplication				
yes	0 (0)	0 (0)	0 (0)	NA
no	10 (100)	10 (100)	10 (100)	
Volume of Blood Loss (ml) median (min-maks)	125,0 (20–200)	100,0 (30–150)	100,0 (50–250)	0,725 ^a
Length of stay (day)	4 (3–4)	4 (3–5)	4 (3–4)	0.748 ^a

CUSUM Analysis of Learning Curves

To evaluate the learning progression of each trainee, a Cumulative Sum (CUSUM) analysis was performed. This method monitors sequential changes in performance over time and detects shifts toward improvement or decline. The calculation followed the formula below. The C_i is the updated CUSUM value, C_{i-1} is the previous cumulative sum, X_i is the observed operative time or blood loss for the i -th case, T is the benchmark (target or reference value). Benchmark times were established at 33 minutes for TVH, 17 minutes for KA, 36 minutes for KPR, and 44 mL for intraoperative blood loss, based on prior studies and institutional reference data. For example,

Gabra et al. (2022) reported a mean TVH duration of 34 minutes in 1,162 cases, from which the local benchmark of 33 minutes was derived. The same approach was applied for other procedures.

$$C_i = C_{i-1} + (X_i - T)$$

CUSUM analysis of TVH operative times revealed distinct learning trajectories among trainees. Participant A demonstrated a gradual improvement with consistent reduction in operative time through the sixth case, reaching a plateau between cases 9 and 10, indicated by a negative deviation and reduction in CUSUM from 167 to 144. Participant B showed a rapid improvement between cases 1–5, achieving performance stabilization by the sixth procedure. Participant C demonstrated a steep improvement phase in cases 1–5, followed by a relatively stable performance after the sixth case.

For anterior colporrhaphy (KA), Participant A exhibited a progressive improvement from cases 1–7 and plateaued after case 8. Participant B displayed early consistency and achieved stability as early as the fourth procedure, suggesting faster skill acquisition. Participant C demonstrated steep improvement between cases 1–5 and reached a stable plateau by case 6. These findings suggest comparable end-proficiency but variable rates of early learning across participants.

CUSUM analysis of colpoperineorrhaphy (KPR) procedures showed that Participant A achieved a steady improvement trend, reaching performance plateau at case 6. Participant B improved rapidly, peaking at case 4, followed by a gradual decline in CUSUM through case 10. This indicates shorter operative times relative to the benchmark. Participant C demonstrated initial improvement (cases 1–5) but showed an increase in operative time toward the later cases, suggesting case-specific challenges or patient variability. The summarized values of CUSUM calculations are presented in (Table 3). When analyzing total operative time across all procedures (TVH, KA, and KPR combined), Participant A showed a consistent improvement trend with stabilization by case 6. Participant B achieved plateau earlier at case 4. While Participant C reached stable performance by case 6.

Table 3. CUSUM Analysis ttrainee A, B, and C in Urogynecology

No.	Trainee A			Trainee B			Trainee C		
	Xi	Xi-44	Ci	Xi	Xi-44	Ci	Xi	Xi-44	Ci
0	(Inisial)		0	(Inisial)		0	(Inisial)		0
1	100	55	55	40	-5	-5	250	205	205
2	150	105	160	150	105	100	50	5	210
3	150	105	265	100	55	155	150	105	315
4	200	155	420	100	55	210	50	5	320
5	50	5	425	50	5	215	100	55	375
6	200	155	580	100	55	270	50	5	380
7	150	105	685	100	55	325	50	5	385
8	150	105	790	150	105	430	100	55	440
9	50	5	795	80	35	465	100	55	495
10	20	-25	770	30	-15	450	200	155	650

CUSUM analysis of intraoperative blood loss followed the same calculation principles. Using a baseline benchmark of 44 mL, derived from prior literature, performance curves were generated for each trainee. Participant A achieved plateau by case 4, demonstrating rapid improvement in hemostatic control. Participant B also stabilized by case 4, while Participant C reached performance stability by case 5. These results are shown in (Figure 1 to 4).

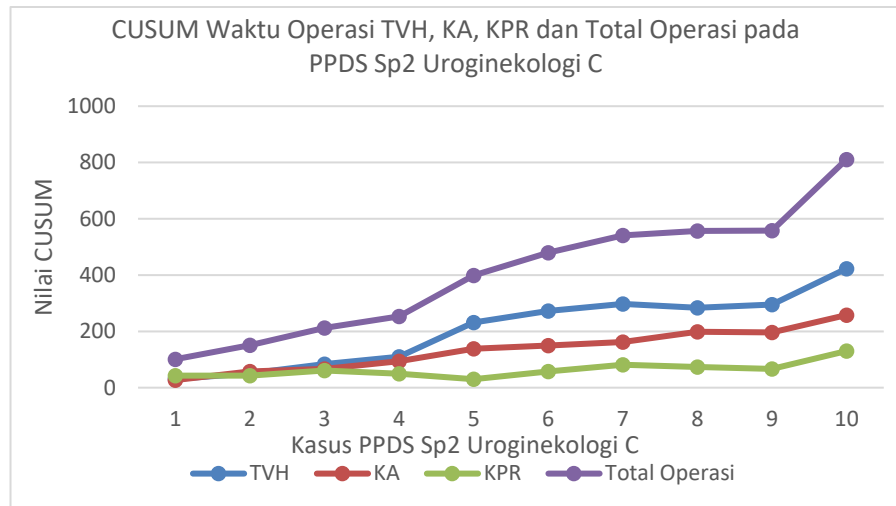


Figure 1. CUSUM CHART Trainee A

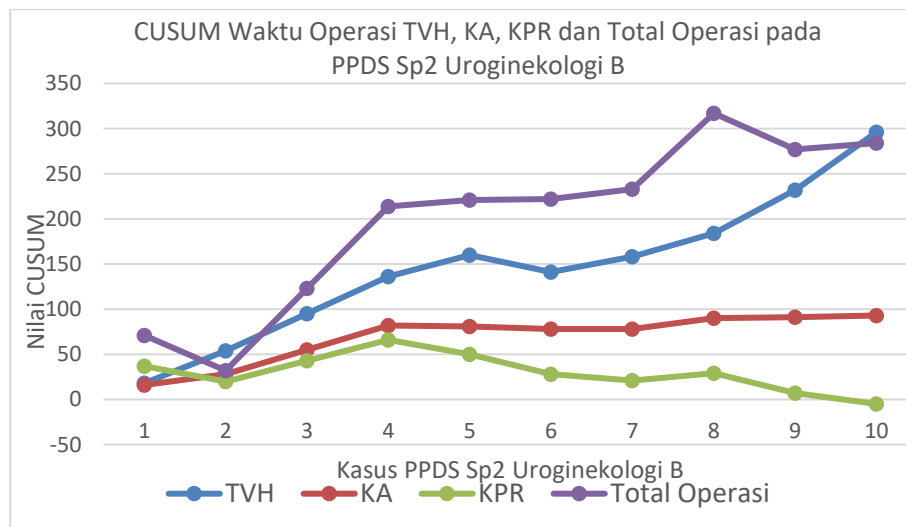


Figure 2. CUSUM CHART Trainee B

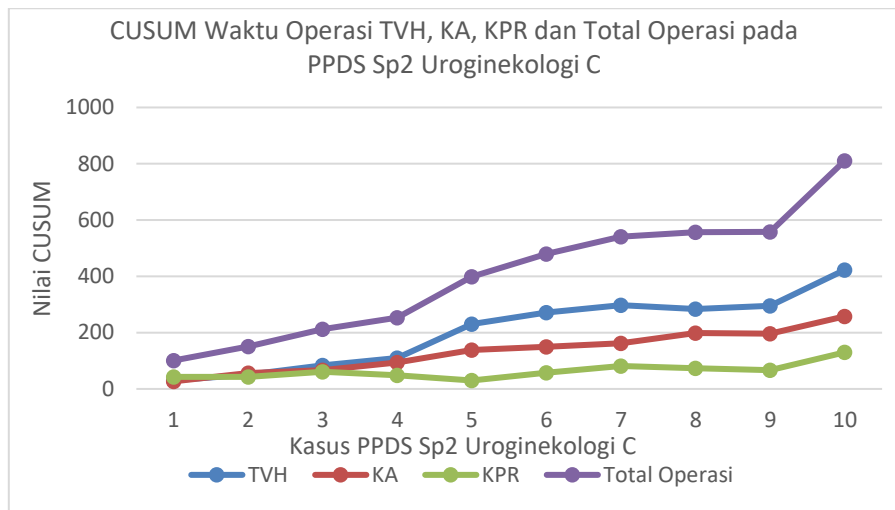


Figure 3. CUSUM CHART Trainee C

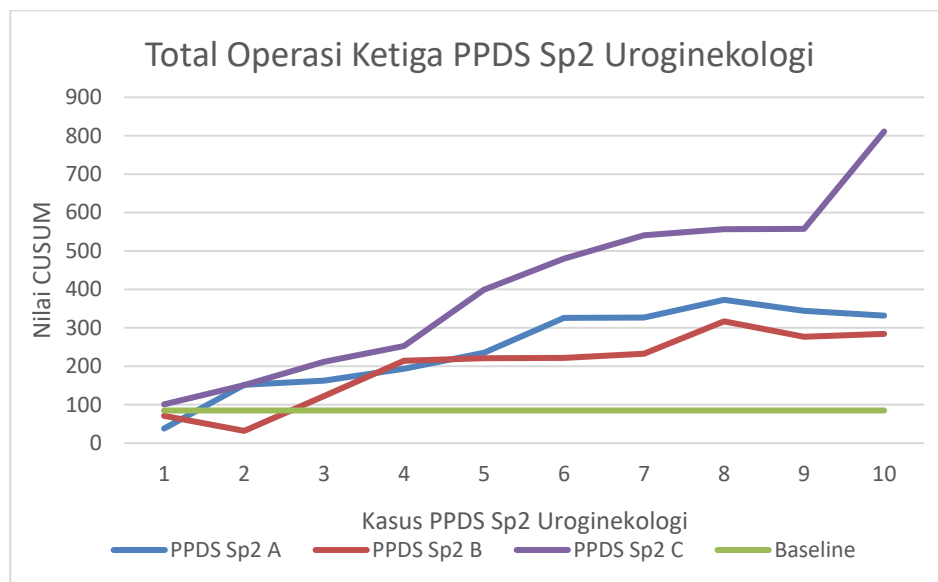


Figure 4. CUSUM CHART duration Trainee A, B and C

DISCUSSION

This study involved three third-semester subspecialty trainees in Urogynecology and Aesthetic Reconstructive Surgery participated in this study. Participant A was a 38 year old male obstetrician-gynecologist with five years of clinical experience and prior exposure to five pelvic organ prolapse (POP) surgeries. Participant B was a 43 year old female with ten years of clinical experience and two prior POP procedures, while Participant C was a 36 year old female with five years of experience and five previous POP operations. All participants had completed one year of subspecialty training at the start of this study.

We found that gender did not appear to influence operative learning outcomes in this study.

The CUSUM analysis demonstrated no significant differences between male and female trainees. This finding aligns with previous research by Benissan-Messan et al. (2023), who analyzed 4,417 surgical cases performed by trainees in the United States and found no association between gender and acquisition of surgical skills.² Similarly, Kolozsváro et al. (2011) and Fjortoft et al. (2022) reported no significant gender-related differences in technical ability or learning curve progression among medical trainees.^{3,4} Collectively, these studies support the current findings that gender does not significantly affect technical surgical performance during training.

Age likewise did not demonstrate a clear relationship with operative proficiency. Chronological age alone cannot adequately represent technical ability or clinical experience, particularly when trainees may begin subspecialty education at varying stages in their careers. Participants in this study were aged 38, 43, and 36 years, respectively, with participant C being the youngest. Despite being younger, participant C exhibited a relatively steep CUSUM curve in total operative duration, particularly around the fifth and tenth cases. However, this variation likely due to case complexity rather than age-related factors. Bhatt NR et al. (2016) emphasized that operative efficiency correlates more closely with functional age (a composite of cognitive, physical, and technical capacity) rather than chronological age.^{5,6} Moreover, Satkunasivam R et al. (2020) observed no evidence that older surgeons have longer operative times. They found that patients of surgeons over 65 years exhibited slightly better postoperative outcomes.⁷ Consistent with these findings, the present study concludes that age is not an influential determinant of operative performance within this non-geriatric cohort.

In contrast, years of experience as a general obstetrician-gynecologist appeared to affect surgical learning. Participant B, who had the longest practice history (10 years), reached a CUSUM plateau earlier (after the fourth case) than the others, despite having performed fewer POP procedures previously. This pattern suggests that accumulated general surgical exposure enhances adaptability and technical precision in specialized procedures. Salehi-Pourmehr et al. (2025), in a systematic review of 68 urogynecologic learning-curve studies, similarly concluded that operator experience and prior case volume are key determinants of operative duration and efficiency.⁸ According to Szymczak P et al. (2021), proficiency in laparoscopic pectopexy was typically achieved after 28 cases.⁹ Both studies corroborate the principle that higher prior exposure expedites skill acquisition, a finding mirrored in participant B's steeper progression curve in the current study.

It should be acknowledged that other intrinsic trainee factors such as attitude, innate aptitude, motivation, and capacity to assimilate new psychomotor skills, may also influence learning curves.¹⁰ However, these variables were not formally evaluated in this investigation.

Characteristics of Operated Patients

Thirty patients undergoing POP surgery were included, with a mean age of 63 ± 3.5 years. The majority (73.3%) were aged > 60 years, consistent with prior research indicating that POP symptoms typically manifest in postmenopausal women. Szymczak P et al. (2013) reported a similar mean age (62.6 ± 8.5 years), while Wu CJ et al. (2022) noted a slightly higher mean (66.7 ± 10.8 years).^{1,9} Age-related weakening of pelvic connective tissue, driven by altered collagen synthesis,

reduced type I and increased type III collagen, contributes to the mechanical instability of pelvic support structures.^{11–13}

The mean body mass index (BMI) in this cohort was 24.65 ± 1.55 kg/m², with 66.7% categorized as obese using Asian criteria (BMI > 23). Obesity is a recognized risk factor for POP, with each unit increase in BMI raising risk by approximately 3% [67]. While Western studies (Sagnic 2021; Szymczak 2013; Glazener 2013) reported higher mean BMIs (≈ 27 kg/m²).^{9,14,15} Such differences likely reflect distinct WHO obesity thresholds applied in non-Asian populations. However, Wu CJ et al. (2022) documented comparable BMI values among Southeast Asian patients with BMI of 24.5 ± 3.32 kg/m², supporting the current findings.¹

Parity also emerged as an important characteristic: 67% of patients were multiparous and 33% grand multiparous (median = 3 deliveries). Higher parity is an established independent risk factor for POP surgery, conferring up to ninefold increased risk among grand multiparas.¹³ These findings align with prior studies by Levy et al. (2024), Lee et al. (2017), and Wu CJ et al. (2022), all demonstrating that surgical POP correction is more common in women with high parity.^{1,13,16}

No patients with mild POP (stage I or II) were included, as surgical intervention is typically reserved for symptomatic stage III and IV disease. In this study, 43.3% of patients had stage III and 56.7% had stage IV prolapse, consistent with Levy et al. (2024) and Wu CJ et al. (2022), who reported that higher POP-Q grades are the primary surgical indications.^{1,16} POP-Q staging also correlates with operative and postoperative outcomes, particularly in the anterior vaginal wall (Ba < 1.0 cm postoperatively as an anatomic success predictor).

No significant differences in patient demographics were observed among the three trainee groups. Although participant B's patients were older and more likely to have comorbidities (70%), this did not translate to increased operative time, blood loss, or complications. Meanwhile, participant C's group contained more obese patients and higher-grade POP, resulting in longer median operative durations (150 min), yet without excessive bleeding or major complications. Thus, obesity and advanced prolapse grade may increase surgical complexity but do not independently predict poor learning performance.

Stress urinary incontinence (SUI) was most common in patients operated on by participant A (80%). However, no significant difference in operative duration was observed between patients with and without SUI, consistent with prior findings that operative time largely depends on surgical technique rather than the presence of concomitant incontinence.^{17–19} Similarly, cervical elongation and levator ani ballooning—conditions expected to prolong specific operative steps—were evenly distributed among groups and did not significantly influence the overall CUSUM trajectory.

CUSUM Analysis of Operative Duration and Blood Loss

CUSUM (Cumulative Sum) analysis was used to model learning curves for three major POP reconstructive procedures: total vaginal hysterectomy (TVH), anterior colporrhaphy (KA), and colpoperineorrhaphy (KPR). Median operative durations were 61 minutes (TVH), 32.5 minutes (KA), and 35.5 minutes (KPR). These times were longer than those reported by Gabra et al. (2022), who

observed a 34 minutes median for TVH in 1,162 cases a discrepancy likely due to smaller sample size, narrower patient selection, and greater uterine size variability in the prior study.²⁰ Benchmark durations were set at 33, 17, and 36 minutes for TVH, KA, and KPR respectively, with a reference blood loss of 44 mL. All three trainees demonstrated a steep initial improvement phase followed by a plateau at different points: participant A and C plateaued at case 6, while participant B reached stability by case 4. This pattern reflects the classical learning curve trajectory, comprising an initial rapid learning phase and subsequent plateau signifying competence.

Comparison with international data suggests that proficiency in POP reconstruction typically requires > 30 independent procedures. Wu CJ et al. (2022) reported proficiency after 32–33 vaginal POP reconstructions.¹ Szymczak et al. (2021) and Van Zanten et al. (2019) identified similar thresholds ($\approx$ 38–78 cases) [57–58]. Given that each trainee in this study performed only 10 cases, the observed plateau likely indicates transition from the novice to competent phase rather than full proficiency.^{9,21} This interpretation is supported by Park K et al. (2024), who identified comparable CUSUM phase shifts at case 9 and 35 in a robotic sacrocolpopexy series.²²

CUSUM analysis of intraoperative blood loss revealed plateau formation at case 4 for participants A and B and at case 5 for participant C. Although fluctuations were observed, particularly during prolonged or complex cases (e.g., case 8 of B and case 10 of C), overall intraoperative bleeding remained within acceptable limits (typically < 200 mL). These findings correspond with Szymczak et al. (2021), who noted non-significant blood-loss variability in similar laparoscopic POP reconstructions.⁹ Currently, limited evidence addresses the relationship between CUSUM-derived bleeding metrics and operative learning, indicating a need for further studies incorporating this parameter as an adjunct competency marker.

CONCLUSION

This study highlights the utility of the CUSUM method as a sensitive and objective tool for monitoring technical skill acquisition among urogynecology trainees. Even with a limited number of cases, CUSUM analysis effectively detected incremental improvements and stabilization of performance. The absence of major complications across all procedures reflects the safety of the structured, tiered supervision system employed in this training program. Moreover, integrating CUSUM into surgical education supports a competency-based medical education (CBME) framework, aligning with World Health Organization (WHO) recommendations for outcome-based training. Routine use of CUSUM analytics allows individualized feedback, early identification of learning plateaus, and evidence-based adjustments to supervision intensity. These findings underscore the method's dual value as both a pedagogical and quality-assurance instrument in surgical education, ensuring that trainees achieve technical competence without compromising patient safety.

REFERENCES

1. Benissan-Messan DZ, Tamer R, Pieper H, Meara M, Chen X (Phoenix). What factors impact surgical operative time when teaching a resident in the operating room. *Heliyon*. 2023 Jun;9(6):e16554.
2. Kolozsvari NO, Andalib A, Kaneva P, Cao J, Vassiliou MC, Fried GM, et al. Sex is not everything: the role of gender in early performance of a fundamental laparoscopic skill. *Surg Endosc*. 2011 Apr 24;25(4):1037–42.
3. Fjørtoft K, Konge L, Christensen J, Thinggaard E. Overcoming Gender Bias in Assessment of Surgical Skills. *J Surg Educ*. 2022 May;79(3):753–60.
4. Bhatt NR, Morris M, O’Neil A, Gillis A, Ridgway PF. When should surgeons retire? *Journal of British Surgery*. 2016 Jan 1;103(1):35–42.
5. Soto-Perez-de-Celis E, Li D, Yuan Y, Lau YM, Hurria A. Functional versus chronological age: geriatric assessments to guide decision making in older patients with cancer. *Lancet Oncol*. 2018 Jun;19(6):e305–16.
6. Satkunasivam R, Klaassen Z, Ravi B, Fok KH, Menser T, Kash B, et al. Relation between surgeon age and postoperative outcomes: a population-based cohort study. *Can Med Assoc J*. 2020 Apr 14;192(15):E385–92.
7. Salehi-Pourmehr H, Tahmasbi F, Hosseinpour S, Nouri O, Lotfi B, Iranmanesh P, et al. The Learning Curve in Urogynecology and Functional Urology: A Systematic Review. *Int Urogynecol J*. 2025 Jun 16;36(6):1123–48.
8. Szymczak P, Grzybowska ME, Sawicki S, Wydra DG. Laparoscopic pectopexy—CUSUM learning curve and perioperative complications analysis. *J Clin Med*. 2021;10(5):1052.
9. Valsamis EM, Chouari T, O’Dowd-Booth C, Rogers B, Ricketts D. Learning curves in surgery: variables, analysis and applications. *Postgrad Med J*. 2018;94(1115):525–30.
10. Wu CJ, Huang KJ, Chang WC, Li YX, Wei LH, Sheu BC. Analyzing the learning curve of vaginal pelvic reconstruction surgery with and without mesh by the cumulative summation test (CUSUM). *Sci Rep*. 2022;12(1):7025.
11. Santoso BI, Fauziah NR. Prevalence and characteristics of pelvic floor dysfunction in a Tertiary Care Center in Indonesia. *Indonesian Journal of Obstetrics and Gynecology*. 2017;168–72.
12. Gosain A, DiPietro LA. Aging and wound healing. *World J Surg*. 2004;28(3):321–6.
13. Lee UJ, Kerkhof MH, Van Leijssen SA, Heesakkers JP. Obesity and pelvic organ prolapse. *Curr Opin Urol*. 2017;27(5):428–34.
14. Sağrıç S, Kokanalı MK, Cavkaytar S, Doğanay M. The impact of delivery mode and parity on development of pelvic organ prolapse and urinary incontinence. *Jinekoloji-Obstetrik ve Neonatoloji Tıp Dergisi*. 2021;18(4):1010–6.
15. Glazener C, Elders A, MacArthur C, Lancashire RJ, Herbison P, Hagen S, et al. Childbirth and prolapse: long-term associations with the symptoms and objective measurement of pelvic organ prolapse. *BJOG*. 2013;120(2):161–8.
16. Levy G, Lindo FM, Lozo S, Prodigalidad L, Brito LGO, Lo TS, et al. A Roadmap for Training in Urogynecology: IUGA International Initiative. *Int Urogynecol J*. 2024;1–5.

17. Altman D, Forsman M, Falconer C, Lichtenstein P. Genetic influence on stress urinary incontinence and pelvic organ prolapse. *Eur Urol.* 2008;54(4):918–23.
18. Cai Y, Su K, Bian A. Comparing combined paravaginal repair with pubocervical fascia plication versus standard anterior colporrhaphy for the treatment of stress urinary incontinence in women with anterior vaginal wall prolapse: a randomised controlled trial. *Arch Gynecol Obstet.* 2024 Dec 29;311(1):163–73.
19. Ramadan DT, Elhefnawy AS, Wadie BS. The use of midurethral sling in the correction of low-stage cystoceles: a prospective randomized trial. *Int Urogynecol J.* 2024 Jan 4;35(1):199–205.
20. Gabra MG, Tessier KM, Fok CS, Nakib N, Oestreich MC, Fischer J. Pelvic organ prolapse and anal incontinence in women: screening with a validated epidemiology survey. *Arch Gynecol Obstet.* 2022;306(3):779–84.
21. van Zanten F, Koops SES, Pasker-De Jong PCM, Lenters E, Schreuder HWR. Learning curve of robot-assisted laparoscopic sacrocolpo (recto) pexy: a cumulative sum analysis. *Am J Obstet Gynecol.* 2019;221(5):483. e1-483. e11.
22. Park K, Kwon JY, Yoo EH, Lee SH, Song JM, Pyeon SY. Application of CUSUM analysis in assessing learning curves in robot-assisted sacrocolpopexy performed by experienced gynecologist. *BMC Surg.* 2024 Dec 4;24(1):385.