

Factors Affecting Positive Surgical Margins in Patients Who Underwent Loop Electrosurgical Excision Procedure

Apichaya Kuamanee, MD¹, Sithchuphong Noothong, MD¹

¹ Department of Obstetrics and Gynecology, Hatyai Hospital, Hat Yai, Songkhla, Thailand

ABSTRACT

Objective: To identify the factors affecting positive surgical margins from the loop electrosurgical excision procedure (LEEP) on the cervix. The secondary objective is to determine the optimal depth for LEEP on the cervix, resulting in no detectable lesions at the tissue margins.

Materials and Methods: The authors conducted a retrospective cohort study of those who underwent colposcopy and LEEP at Hatyai Hospital between November 2016 and August 2023. Statistical analyses, including univariate and multivariate logistic regression analyses, were performed to identify factors associated with positive surgical margins. The optimal depth of LEEP for achieving negative surgical margins was calculated using a receiver operating characteristic (ROC) curve.

Results: Two hundred thirty-seven patients were included; 115 (48.5%) had positive surgical margins, and 122 (51.5%) had negative surgical margins. Unsatisfactory colposcopy (adjusted OR 1.78, 95% CI 1.03 to 3.07), endocervical glandular involvement (aOR 2.90, 95% CI 1.62 to 5.19), and LEEP performed by residents (aOR 2.15, 95% CI 1.01 to 4.58) were associated with increased risk of positive surgical margins. The optimal depth of LEEP to achieve negative surgical margins is greater than 1.5 centimeters, with a sensitivity of 80.9%, a specificity of 27%, a positive predictive value of 51.1%, and a negative predictive value of 60%.

Conclusion: Unsatisfactory colposcopy, endocervical glandular involvement, and the surgeon's factor are significantly associated with positive surgical margins. An excisional depth greater than 1.5 cm may increase the likelihood of negative surgical margins. Clinical practice guidelines should emphasize the importance of adequate colposcopy and the practitioner's experience in reducing the incidence of positive surgical margins.

Keywords: Uterine cervical dysplasia; Colposcopy; Conization; Margins of excision; Endocervical gland involvement

Received 4 October 2025 | Revised 14 April 2026 | Accepted 16 April 2026

J Med Assoc Thai 2026;109(10):816-22

<https://doi.org/10.35755/jmedassocthai.2026.10.03651>

Currently, cervical cancer ranks as the fourth most common cancer among women globally and is the fourth leading cause of cancer-related deaths in women worldwide⁽¹⁾. In Thailand, cervical cancer is the fourth most common cancer among Thai women⁽²⁾. Early detection of this cancer with a screening program can reduce mortality rates by 41% to 92%⁽³⁾. According to the 2021 RCOG Clinical Practice Guideline⁽⁴⁾ on Cervical Cancer Screening, the currently recommended screening modalities include human papillomavirus (HPV)-based testing, liquid-based cytology (Pap

smear), and co-testing, which combines HPV-based testing with cervical cytology at different screening intervals.

Cervical intraepithelial neoplasia grade 1 (CIN 1) has a 60% to 85% chance of regressing within 2 years. Patients with CIN 1 can be observed and managed with 1-year surveillance using HPV-based testing following colposcopy with biopsy, according to the

What is already known about this topic?

Positive surgical margins after LEEP have been reported in approximately 10% to 30% of patients treated for high-grade cervical intraepithelial neoplasia. Previous studies have identified several factors associated with margin positivity, including endocervical glandular involvement, multiparity, advanced age, and inadequate colposcopic visualization. In addition, the optimal cone depth required to achieve negative surgical margins remains controversial, with substantial variation across studies and no clear consensus, particularly in balancing oncologic adequacy and potential obstetric complications.

What does this study add?

This study adds evidence from a large tertiary care center in southern Thailand indicating that unsatisfactory colposcopy, endocervical glandular involvement, and the surgeon's level of experience are independently associated with positive surgical margins following LEEP. In addition, this study suggests that an excision depth greater than 1.5 centimeters may be a practical cutoff point to improve the likelihood of achieving negative surgical margins in routine clinical practice.

Correspondence to:

Kuamanee A.
Department of Obstetrics and Gynecology, Hatyai Hospital, Hat Yai,
Songkhla 90110, Thailand.
Phone: +66-74-273138
Email: apichaya.kuamanee@gmail.com
ORCID: 0009-0006-1631-4268

How to cite this article:

Kuamanee A, Noothong S. Factors Affecting Positive Surgical Margins in Patients Who Underwent Loop Electrosurgical Excision Procedure. J Med Assoc Thai 2026;109:816-22.

2019 ASCCP guidelines⁽⁵⁾. Patients with CIN 2 or CIN 3 should undergo conization (the surgical removal of a cone-shaped section of the transformation zone of the cervix) or ablative therapy to eliminate the lesion at the transformation zone of the cervix. Generally, conization is preferred over ablative therapy because it allows for pathological examination of the removed tissue, carries a lower risk of treatment failure and disease recurrence⁽⁶⁾, and is an appropriate treatment option in cases with abnormal endocervical glandular involvement.

Currently, there are three main methods of conization for cervical intraepithelial neoplasia: 1) Loop electrosurgical excision procedure (LEEP), 2) Cold knife conization, and 3) Laser conization. Among these procedures, LEEP is the preferred method for conization⁽⁷⁾ because it offers a shorter surgical time and is easier to perform⁽⁸⁾. Moreover, the recurrence rate of precancerous lesions and pregnancy outcomes after LEEP are similar to those who are excised with cold knife conization and laser conization.

However, about 30% of the patients who were treated with LEEP still have residual disease⁽⁹⁾. Some research papers from Thailand have identified multiparity, advanced age, greater lesion involvement in multiple quadrants, and glandular involvement as risk factors for positive surgical margins^(10,11).

The optimal depth of conization varies, and there are currently no consensus guidelines or recommendations. Using a receiver operating characteristic (ROC) curve, a study by Srijarusith & Rodpenpear⁽¹¹⁾ determined that the optimal depth for achieving negative surgical margins is 7.21 millimeters, with a sensitivity of 63.53% and specificity of 71.67%. In contrast, a study by Beyer et al.⁽¹²⁾ found that a depth of 20 millimeters or greater could achieve 100% negative surgical margins, while a depth between 10 and 19.9 millimeters resulted in a 73% rate of negative surgical margins. However, if the cone depth is too deep, it may adversely impact obstetrical outcomes, increasing the risk of late miscarriages and premature labor⁽⁷⁾.

Therefore, the optimal depth for achieving negative surgical margins remains inconclusive. Previous studies have reported positive surgical margins after LEEP in approximately 10% to 30% of patients with high-grade cervical lesions, with endocervical gland involvement, multiparity, and inadequate colposcopy being common contributing factors. However, the appropriate cone depth to achieve complete excision varies widely among studies. These results raise questions about the factors that increase the

likelihood of detecting residual precancerous lesions at the cervical margins after LEEP, which could lead to the persistence or recurrence of precancerous cervical lesions.

This research aims to identify the factors affecting positive surgical margins and determine the optimal depth of LEEP using patient data from Hatyai Hospital.

MATERIALS AND METHODS

After the study protocol was approved by the Human Research Ethics Committee at Hatyai Hospital (Approval No. HYH EC 114-66-01), a retrospective cohort study was conducted in 237 patients who underwent colposcopy and LEEP between November 2016 and August 2023.

Clinical data were retrieved from medical records, including age, parity, HIV status, HPV test results, Pap smear results, colposcopic findings, surgeon, glandular involvement, and pathological results from colposcopic biopsy and LEEP specimens.

The inclusion criteria comprised patients diagnosed with precancerous cervical lesions who underwent colposcopy and LEEP for the first time. The exclusion criteria included unclear or incomplete data, a history of prior LEEP, and the absence of precancerous lesions in the pathological evaluation obtained from LEEP.

The indications for LEEP included histologic findings of CIN 2 or CIN 3 from cervical biopsy or endocervical curettage, as well as cytopathologic discrepancies. Colposcopy was performed by gynecologic oncologists in all cases, while LEEP was performed by residents under staff supervision, general gynecologists, and gynecologic oncologists. A positive surgical margin was defined as the presence of cervical intraepithelial neoplasia or a higher-grade lesion at the tissue margin.

The sample size was calculated based on the most potential risk factors for positive surgical margin, specifically satisfaction of colposcopy and endocervical gland involvement, using data from Srijarusith & Rodpenpear⁽¹¹⁾ and applying Fisher's exact test with a 5% chance of making a type I error. Additionally, to determine the optimal depth for LEEP, we calculated the sample size from Hanley and McNeil's formula for area under receiver operating characteristic (AUROC) curve sample size calculation with AUROC 0.7374 derived from a study by Srijarusith & Rodpenpear⁽¹¹⁾; the final calculated sample size was 212 patients. To account for potential dropouts, we increased the sample size by 10%, resulting in a required minimum of 234 patients.

Electronic medical records and pathological results

Table 1. Characteristic features of the study population (n=237)

Characteristics	Total	Positive margin	Negative margin	p-value
Age (years); median (IQR)	42 (35, 48)	45 (35, 50)	40.5 (34, 47)	0.008
PAP smear; n (%)				0.538
NILM	2 (1.1)	1 (1.1)	1 (1.1)	
ASC-US	20 (10.8)	8 (8.7)	12 (12.8)	
LSIL	14 (7.5)	7 (7.6)	7 (7.4)	
ASC-H	43 (23.1)	17 (18.5)	26 (27.7)	
HSIL	88 (47.3)	46 (50)	42 (44.7)	
SCCA	9 (4.8)	5 (5.4)	4 (4.3)	
AGC	7 (3.8)	5 (5.4)	2 (2.1)	
AIS	1 (0.5)	1 (1.1)	0 (0.0)	
Adenocarcinoma	2 (1.1)	2 (2.2)	0 (0.0)	
Colposcopy impression; n (%)				0.026
Normal ectocervix	19 (16.5)	10 (8.2)	29 (12.2)	
LGL	23 (20.0)	39 (32.0)	62 (26.2)	
HGL, invasive cancer	69 (60.0)	72 (59.0)	141 (59.5)	
Atrophy	3 (2.6)	0 (0.0)	3 (1.3)	
Cervicitis	1 (0.9)	1 (0.8)	2 (0.8)	
LEEP pathology; n (%)				<0.001
CIN 1	18 (7.6)	2 (1.7)	16 (13.1)	
CIN 2-3	185 (78.1)	88 (76.5)	97 (79.5)	
CIS	13 (5.5)	8 (7.0)	5 (4.1)	
SCCA	8 (3.4)	8 (7.0)	0 (0.0)	
AIS	10 (4.2)	6 (5.2)	4 (3.3)	
Adenocarcinoma	3 (1.3)	3 (2.6)	0 (0.0)	

NILM=negative intraepithelial lesion or malignancy; ASC-US=atypical squamous cell of undetermined significance; LSIL=low-grade squamous intraepithelial lesion; ASC-H=atypical squamous cell cannot exclude HSIL; HSIL=high-grade squamous intraepithelial lesion; SCCA=squamous cell carcinoma; AGC=atypical glandular cells; AIS=adenocarcinoma in situ; CIN=cervical intraepithelial neoplasia; CIS=carcinoma in situ

from the Hatyai Hospital program were collected. Data were analyzed using R Statistical Software, version 4.3.1. Demographic data were analyzed using descriptive statistics. Continuous data were reported as medians with interquartile ranges (IQR), while categorical data were presented as percentages. Factors associated with positive surgical margins after LEEP were analyzed using univariate logistic regression analyses. Factors with p-values between 0.05 and 0.1 were subsequently entered in multivariate logistic regression analyses. Risk factors for positive surgical margins were reported as odds ratios (ORs) with 95% confidence intervals (CIs), along with p-values from Wald's test and the likelihood ratio (LR) test. Statistical significance was defined as a p-value of less than 0.05.

The optimal depth of LEEP to achieve negative surgical margins was determined using an ROC curve, with the maximum AUROC calculated using R Statistical Software, version 4.3.1, to identify the most suitable cutoff point, along with sensitivity, specificity, positive predictive value, and negative predictive value.

RESULTS

During the study period, 516 patients underwent LEEP, including both first-time and repeat procedures. Of these, 279 were excluded because of prior LEEP, incomplete histopathological data, or missing documentation of colposcopic or intraoperative LEEP findings. Consequently, 237 patients with precancerous cervical lesions who underwent first-time LEEP were included in the final analysis.

Baseline clinicopathologic characteristics of the study population are summarized in Table 1. The positive surgical margins and negative surgical margins groups were significantly different in terms of age and LEEP pathology. Other characteristics were similar. The patients' ages ranged from 17 to 77 years, with a median age of 45 years in the positive surgical margins group and 40.5 years in the negative surgical margins group. Most of the patients were multiparous (84%). HIV infection was diagnosed in 12.7% of the patients.

A total of 78.4% of the patients received a PAP smear screening, while 35% were screened with HPV

Table 2. Factors associated with LEEP margin involvement (n=237)

Factors	n (%)		OR (95% CI)	p-value
	Positive margin	Negative margin		
Parity				
Multiparous	100 (87.0)	99 (81.1)	1.55 (0.76 to 3.14)	0.225
Nulliparous	15 (13.0)	23 (18.9)	Reference	
HIV infection				
Yes	17 (14.8)	13 (10.7)	1.45 (0.67 to 3.15)	0.341
No	98 (85.2)	109 (89.3)	Reference	
HPV infection				
HPV 16	25 (67.6)	25 (54.3)	1.44 (0.52 to 3.98)	0.478
HPV 18	3 (8.1)	8 (17.4)	0.54 (0.11 to 2.62)	0.446
HPV non-16, 18	9 (24.3)	13 (28.3)	Reference	
Satisfaction with colposcopy				
Unsatisfactory	56 (48.7)	46 (37.7)	1.57 (0.93 to 2.63)	0.088
Satisfactory	59 (51.3)	76 (62.3)	Reference	
Surgeon				
Resident	25 (21.7)	18 (14.8)	2 (0.97 to 4.13)	0.061
General gynecologist	49 (42.6)	45 (36.9)	1.57 (0.89 to 2.77)	0.121
Gynecologic oncologist	41 (35.7)	59 (48.4)	Reference	
Glandular involvement				
Yes	88 (76.5)	68 (55.7)	2.59 (1.48 to 4.53)	<0.001
No	27 (23.5)	54 (44.3)	Reference	
Depth of cone (cm)				
<1.5	93 (81.0)	89 (73)	Reference	
≥1.5	22 (19.0)	33 (27)	0.64 (0.35 to 1.18)	0.151

HPV=human papillomavirus; OR=odds ratio; CI=confidence interval

DNA testing. Some patients were screened with both PAP smear and HPV testing. Among the 83 patients tested for HPV infection, 60.2% were infected with HPV 16, 13.3% with HPV 18, and 26.5% with HPV non-16,18 types. Among the 185 patients screened with a PAP smear, the most common result was high-grade squamous intraepithelial lesion (HSIL) at 47.3%, followed by atypical squamous cells, cannot exclude HSIL (ASC-H) (23.1%).

Colposcopy was performed by gynecologic oncologists in all cases, and 57.0% of patients had satisfactory colposcopic findings. The colposcopic impression demonstrated high-grade cervical lesions in most cases (59.5%), followed by low-grade cervical lesions (26.2%). Pathological examination of LEEP specimens revealed CIN 2-3 in 78.1% of cases, while cancer was identified in 4.7% of cases. The rate of positive surgical margins after LEEP in this study was 48.5% (115 of 237 cases), representing nearly half of the patients.

Based on the baseline characteristics presented in [Table 1](#), previously reported risk factors for positive surgical margins, including multiparity and glandular

involvement, as well as other clinically relevant factors, were selected for further analysis. Univariate and multivariate analyses yielded the following results.

A univariate analysis showed that endocervical glandular involvement is a significant factor affecting positive surgical margins, with an OR of 2.59 (95% CI 1.48 to 4.53). Other factors we considered as potential risk factors for positive surgical margins, such as multiparity, HIV infection, high-risk HPV infection, satisfactory colposcopy, and surgeon, were not statistically significant ([Table 2](#)).

After adjusting for potential confounding factors, multivariate analysis demonstrated that unsatisfactory colposcopy significantly affected positive surgical margins, with an OR of 1.78 (95% CI 1.03 to 3.07). Surgeon-related factors significantly impacted surgical margins, as LEEP procedures performed by residents were associated with an increased risk, with an OR of 2.15 (95% CI 1.01 to 4.58). On the contrary, procedures performed by general gynecologists did not lead to a higher rate of positive surgical margins compared to gynecologic oncologists ([Table 3](#)).

The optimal depth of LEEP for achieving negative

Table 3. Multivariable analyses to determine significant factors for positive LEEP margins

Factors	Crude OR (95% CI)	Adjusted OR (95% CI)	p-value
Satisfaction with colposcopy			
Unsatisfactory	1.57 (0.93 to 2.63)	1.78 (1.03 to 3.07)	0.04
Satisfactory	Reference	Reference	
Surgeon			
Resident	2 (0.97 to 4.13)	2.15 (1.01 to 4.58)	0.048
General gynecologist	1.57 (0.89 to 2.77)	1.52 (0.84 to 2.73)	0.164
Gynecologic oncologist	Reference	Reference	
Glandular involvement			
Yes	2.59 (1.48 to 4.53)	2.9 (1.62 to 5.19)	<0.001
No	Reference	Reference	

OR=odds ratio; CI=confidence interval

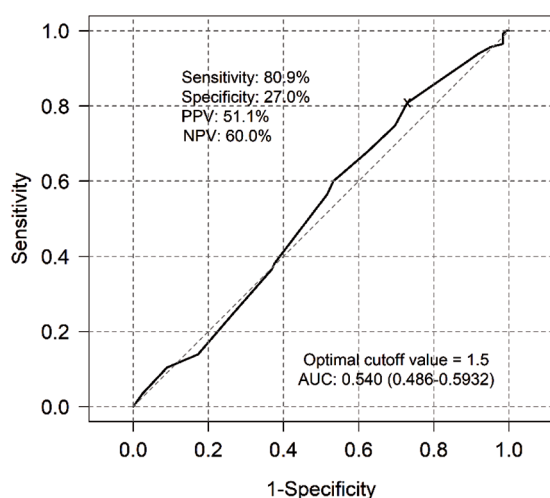


Figure 1. The level of cone depth for negative margin.

surgical margins in this population is greater than 1.5 centimeters, as determined by the ROC curve in [Figure 1](#). This cut-off yielded the highest AUROC and was therefore considered the best threshold for predicting margin status. At this cut-off point, the sensitivity was 80.9%, the specificity was 27.0%, the positive predictive value was 51.1%, and the negative predictive value was 60.0%, with an AUROC of 0.540.

DISCUSSION

This study demonstrated a positive surgical margin rate of 48.5% following LEEP, which is higher than the rates reported in other studies. A study by Kanjanasirirut et al.⁽⁹⁾ reported a positive surgical margin rate of 30.5%, Cong et al.⁽¹³⁾ reported 10%, and Boonlikit et al.⁽¹⁴⁾ reported 13.2%. Our findings provide new evidence from a large tertiary hospital in southern Thailand, confirming that unsatisfactory

colposcopy, endocervical glandular involvement, and the surgeon's level of experience are independent predictors of positive margins. Moreover, we propose an excision depth greater than 1.5 cm as a practical cutoff to achieve negative surgical margins.

A strong risk factor for positive surgical margins identified in this study was glandular involvement as reported in previous studies by Kanjanasirirut et al.⁽⁹⁾ and Srijarusith & Rodpenpear⁽¹¹⁾. Additionally, multivariate logistic regression analysis indicated that satisfactory colposcopy and the surgeon's factors were also significant risk factors.

Satisfactory colposcopy was assessed by gynecologic oncologists in all cases, ensuring the reliability of the results. If the cervix and transformation zone are fully visible, practitioners can be confident that high-grade cervical lesions are identifiable and can be excised accurately. In contrast, if the transformation zone is only partially visible, practitioners may be uncertain about the appropriate excision site, which can lead to incomplete LEEP excision. Thus, a satisfactory colposcopy could explain the results of positive surgical margins, consistent with the study by Srijarusith & Rodpenpear⁽¹¹⁾, in which colposcopies were also performed by gynecologic oncologists. Further research on performing LEEP under colposcopy may improve the success rate of negative surgical margins due to the better visualization of lesions during the procedure.

The surgeon's experience is a significant factor influencing the rate of positive surgical margins. Hatyai Hospital, as a training center for the residency program, allows resident physicians who have less experience to perform LEEP procedures under the supervision of the attending physician responsible for each patient. These supervisors may be a general obstetrician-gynecologist, a gynecologic oncologist, or another obstetrics and gynecologic subspecialist. Residents usually excise a smaller portion of the cervix and to a lesser depth than staff because they are concerned about bleeding or vaginal injury, which leads to a higher rate of positive surgical margins compared to hospitals where gynecologic oncologists always perform LEEP procedures.

There are some risk factors that have previously been reported as significant factors affecting positive surgical margins. Multiparity was reported in the study by Kanjanasirirut et al.⁽⁹⁾, but it was inconsistent with this research. A study by Khunnarong et al.⁽¹⁵⁾ reported that HIV infection was associated with the persistence or recurrence of cervical intraepithelial neoplasia or invasive carcinoma after LEEP, suggesting that disease

recurrence may be linked to positive surgical margins. However, this study found that HIV infection was not a significant risk factor affecting positive surgical margins, but this finding was limited due to the small number of HIV-infected patients included (30 of 237 patients).

The optimal depth for LEEP is greater than 1.5 centimeters with a sensitivity of 80.9%, specificity of 27%, positive predictive value of 51.1%, and negative predictive value of 60%. The AUROC is 0.540. The authors collected the depth of LEEP from the pathological official report, and the depth was reported to one decimal place. A rough approximation of the measurement of cone depth by pathologists may contribute to a low AUROC due to minimal differences between depths. Lacking meticulous measurement may affect the accuracy of the depth assessments, leading to lower specificity, positive predictive value, negative predictive value, and AUROC. The optimal depth for LEEP, which was greater than 1.5 centimeters in this study, could not reliably predict surgical margin outcomes.

The limitations of this study include the lack of review of official pathology reports, the use of approximate cone depth measurements, and the absence of collected data on anesthetic settings. In addition, the sample size was small in some subgroups, such as patients with HIV infection and those with HPV infection.

Regarding anesthetic settings, although these data were not recorded, most LEEP procedures in our practice were performed under total intravenous anesthesia (TIVA), particularly those performed by residents, whereas a minority were performed under local anesthesia. No procedures were performed under general anesthesia.

Future research should involve reevaluating pathological studies by two pathologists and include a larger patient cohort to determine the most accurate optimal depth for LEEP. In addition, further investigation of the combined effects of other risk factors, such as colposcopic findings and glandular involvement, together with operator type, may help identify lesions that are more appropriately managed by experienced physicians rather than residents.

Future practice suggests that practitioners should perform LEEP under colposcopy to ensure better visualization of abnormal lesions of the cervix. Intraoperative measurement of the cone depth should be performed; if the cone depth is less than the optimal cutoff value, the cervix should be excised more deeply to achieve negative surgical margins, thereby

increasing the likelihood of negative surgical margins.

CONCLUSION

The rate of positive surgical margins in this study was 48.5%. Multivariate logistic regression analysis demonstrated that glandular involvement, resident surgeons, and unsatisfactory colposcopy were also significant factors. This study determined that an excisional depth greater than 1.5 centimeters is optimal for achieving negative surgical margins. The study emphasizes the importance of experienced practitioners and adequate colposcopy to reduce positive surgical margins.

Acknowledgement

The authors would like to express their gratitude to all the participants and acknowledge the support provided by the Department of Obstetrics and Gynecology at Hatyai Hospital in Songkhla, Thailand.

Authors Contributions

AK: Conceived and selected the research topic, formulated the research question, developed the study proposal and methodology, and prepared the research protocol and submitted it for ethical approval. She was responsible for data collection and curation, participated in data analysis and interpretation in collaboration with a statistician, and prepared the original manuscript and subsequent revisions. SN: Supervised the research project and contributed to the development and refinement of the research question, assessment of the feasibility and clinical relevance of the study outcomes, data analysis and interpretation in collaboration with the statistician, development of the discussion, and critical review and editing of the manuscript. Both authors reviewed and approved the final version of the manuscript and agreed to be accountable for the accuracy and integrity of the work.

Clinical Trial Registration

Not applicable. This study was a retrospective cohort study and did not involve prospective assignment of participants to an intervention.

Conflicts of Interest

The authors declare no conflict of interest.

Data Availability Statement

The data analyzed in this study were obtained from the PMK electronic medical record system of Hatyai Hospital. Because the data contain confidential patient-level information, they are not publicly available.

Individual medical records are accessible only to authorized hospital personnel using institutionally approved credentials. Requests for access to de-identified study data can be considered upon reasonable request to the corresponding author, subject to approval by Hatyai Hospital and the relevant ethics committee.

Ethics Approval and Consent to Participate

This study was approved by the Human Research Ethics Committee of Hatyai Hospital, Songkhla, Thailand (Study Code: HYH EC 114-66-01), through an expedited review process. No written informed consent was obtained from individual participants because this was a retrospective cohort study using existing medical records, with no direct contact with participants and no prospective intervention or enrollment. The study was conducted in accordance with applicable institutional and ethical requirements.

Funding Disclosure

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Use of Artificial Intelligence

OpenAI ChatGPT (GPT-4o and GPT-5-series models, 2024–2026) was used solely for English-language editing, including grammatical correction and refinement of sentence structure and readability, during manuscript preparation and revision. OpenAI ChatGPT was also used to assist with the visual design of the graphical abstract. AI was not used for study design, data collection, statistical analysis, interpretation of results, or generation of research findings. All AI-assisted content was critically reviewed and verified by the authors, who take full responsibility for the final manuscript and graphical abstract.

REFERENCES

- Global Cancer Observatory. Global cancer statistics [Internet]. Lyon, France: International Agency for Research on Cancer; 2024 [cited 2024 Feb 8]. Available from: <https://gco.iarc.who.int/media/globocan/factsheets/cancers/23-cervix-uteri-fact-sheet.pdf>
- Global Cancer Observatory. Global cancer statistics in Thailand [Internet]. Lyon, France: International Agency for Research on Cancer; 2024 [cited 2024 Feb 8]. Available from: <https://gco.iarc.who.int/media/globocan/factsheets/populations/764-thailand-fact-sheet.pdf>
- Jansen EEL, Zielonke N, Gini A, Anttila A, Segnan N, Vokó Z, et al. Effect of organised cervical cancer screening on cervical cancer mortality in Europe: A systematic review. *Eur J Cancer* 2020;127:207-23.
- Royal Thai College of Obstetricians and Gynaecologists. RCOG clinical practice guideline: Cervical cancer screening. GY 64-017 Bangkok: Royal Thai College of Obstetricians and Gynaecologists; 2021. [in Thai]
- Perkins RB, Guido RS, Castle PE, Chelmow D, Einstein MH, Garcia F, et al. 2019 ASCCP risk-based management consensus guidelines for abnormal cervical cancer screening tests and cancer precursors. *J Low Genit Tract Dis* 2020;24:102-31.
- D'Alessandro P, Arduino B, Borgo M, Saccone G, Venturella R, Di Cello A, et al. Loop electrosurgical excision procedure versus cryotherapy in the treatment of cervical intraepithelial neoplasia: A systematic review and meta-analysis of randomized controlled trials. *Gynecol Minim Invasive Ther* 2018;7:145-51.
- Mathevet P, Chemali E, Roy M, Dargent D. Long-term outcome of a randomized study comparing three techniques of conization: Cold knife, laser, and LEEP. *Eur J Obstet Gynecol Reprod Biol* 2003;106:214-8.
- Mathevet P, Dargent D, Roy M, Beau G. A randomized prospective study comparing three techniques of conization: Cold knife, laser, and LEEP. *Gynecol Oncol* 1994;54:175-9.
- Kanjanasirirut P, Pataradool K, Manusirivithaya S, Phaloprakarn C, Chavanisakun C. Prevalence and risk factors for positive surgical margin after loop electrosurgical excision procedure (LEEP) in patients with high grade squamous intraepithelial lesion. *Thai J Obstet Gynaecol* 2015;23:240-5.
- Yingyongwathanawithaya T, Chirdchim W, Thamrongwuttikul C, Sananpanichkul P. Risk factors for incomplete excision after loop electrosurgical excision procedure (LEEP) in abnormal cervical cytology. *Asian Pac J Cancer Prev* 2017;18:2569-72.
- Srijaruth N, Rodpenpear N. The appropriate of cone depth in loop electrical excision procedure (LEEP) for negative pathological margin from high grade precancerous lesion of cervix, retrospective study. *Asian Pac J Cancer Prev* 2022;23:659-64.
- Beyer DA, Rody A, Schmidt N, Cirkel C, Neumann K. Excisions of severe cervical dysplasia: Are there mandatory diameters of the cone that need to be considered? *J Turk Ger Gynecol Assoc* 2017;18:185-9.
- Cong Q, Yu Y, Xie Y, Li Y, Sui L. Risk factors of LEEP margin positivity and optimal length of cervical conization in cervical intraepithelial neoplasia. *Front Oncol* 2023;13:1209811. doi: 10.3389/fonc.2023.1209811.
- Boonlikit S, Junghuttakarnsatit P, Asavapiriyonont S. Treatment failure following large loop excision of the transformation zone for the treatment of cervical intraepithelial neoplasia at Rajavithi Hospital. *J Med Assoc Thai* 2008;91:31-6.
- Khunnarong J, Bunyasontikul N, Tangjitgamol S. Treatment outcomes of patients with cervical intraepithelial neoplasia or invasive carcinoma who underwent loop electrosurgical excision procedure. *World J Oncol* 2021;12:111-8.