Original Research

Effectiveness of Artificial Intelligence–Assisted Colposcopy in a Resource-Limited Population

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OBJECTIVE: This study evaluates the performance of artificial intelligence (AI) colposcopy in detecting cervical cancer and precancerous lesions in real-world scenarios within resource-limited areas.

METHODS: This is a cross-sectional study. Participants with positive human papilloma virus results or who were cytologic positive were referred for colposcopy, during which AI colposcopy was implemented. Biopsies were performed for positive findings suggested by either the colposcopist or the AI system. For the analysis, we calculated the sensitivity, specificity, positive predictive value, negative predictive value, and area under the curve for detecting cervical intraepithelial neoplasia (CIN) 2+ and CIN 3+. Histopathology was the gold standard for disease diagnosis.

RESULTS: A total of 825 women underwent colposcopy, with 99 (12.0%) diagnosed with CIN 2+ and 53 (6.4%) with CIN 3+. Positive findings were reported in 392 women (47.5%) under conventional colposcopy and 640 (77.6%) with AI colposcopy. The sensitivity for detecting CIN 2+ was significantly higher for AI colposcopy (96.0%) and AI-assisted colposcopy (100%) than for conventional colposcopy (85.9%, $P=.026$, $P<.001$, respectively). In postmenopausal women, the sensitivities of AI colposcopy (94.3%) and AI-assisted colposcopy (100%) surpassed that of conventional colposcopy (77.4%, $P=.026$, $P<.001$, respectively). Artificial intelligence–assisted colposcopy also significantly enhanced the sensitivity of junior colposcopists with less than 10 years of clinical experience, achieving 100% compared with 84.6% by conventional colposcopy ($P=.001$), and improved detection in women with a squamocolumnar junction that was not visible (100% vs 70.4%, $P=.004$). For CIN 3+, the sensitivity of AI-assisted colposcopy was superior to that of conventional colposcopy (100% vs 86.8%, $P=.013$). In postmenopausal women, the sensitivities of both AI colposcopy and AI-assisted colposcopy were 100%; however, the sensitivity of conventional colposcopy was 77.8% ($P=.023$).

CONCLUSION: Artificial intelligence–assisted colposcopy enhances sensitivity in detecting CIN 2+ and CIN 3+, particularly among postmenopausal women. Moreover, it improves the diagnostic performance of junior colposcopists and improves detection in women with a squamocolumnar junction that is not visible.

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Cervical cancer remains a significant global public health issue.[1] In China, the National Cancer Center reported more than 150,700 new cases in

2022, with an average annual increase of 7.3% in cervical cancer incidence over the past two decades.[2] Persistent infection with high-risk human papillomavirus (HPV) is the primary cause of cervical cancer. Organized screening programs are essential for facilitating early diagnosis and treatment, which are critical for reducing the disease burden associated with cervical cancer and improving patient outcomes.[3]

Because of the transient and often autoimmune nature of HPV,[4] HPV infection does not always progress to cervical precancerous lesions. However, its potential risks still require further evaluation with colposcopy and, if necessary, a biopsy to help with diagnosis. However, the accuracy of conventional colposcopy is heavily reliant on clinicians' subjective experience. Discrepancies in diagnostic concordance are common among colposcopists and between colposcopic assessments and histopathologic findings.[5–7] Therefore, enhancing the diagnostic accuracy of colposcopy is crucial to prevent misdiagnosis.[8]

Artificial intelligence (AI) shows great potential in improving the early detection and diagnosis of cancer.[9,10] Multiple studies indicate that AI enhances the accuracy, efficiency, and accessibility of cervical cancer screening and gynecologic examinations.[11,12] Xue et al[13] introduced an AI colposcopy device known as CAIADS (Colposcopic Artificial Intelligence-Assisted Diagnostic System), validated its performance by a retrospective study using anonymized colposcopy images from six Chinese hospitals, and demonstrated that AI colposcopy increased the sensitivity for detecting CIN 2+. Zhao et al[14] used CAIADS and found that AI-assisted conventional colposcopy also improved the sensitivity of CIN 2+ detection. However, both studies focused on hospital-based patients, potentially introducing selection bias on the clinical performance evaluation of AI or AI-assisted colposcopy.

In addition, the effectiveness of colposcopy varies among populations.[15] For instance, in premenopausal women, hormonal shifts and cervical atrophy often render the squamocolumnar junction invisible, complicating conventional colposcopy. Artificial intelligence colposcopy may better address these challenges through deep learning algorithms, improving screening accuracy. The widespread implementation of AI technology has significantly enhanced diagnostic support for health care professionals, particularly in resource-limited settings, thereby contributing to efforts to eliminate cervical cancer.[16,17] Despite this progress, medical professionals remain skeptical of current AI algorithms for cervical cancer screening because of their reliance on highly selective small data sets, the limited representation of real screening populations, and the insufficient diversity in training and testing, which may be addressed through rigorous empirical studies.[18–21]

Our study recruited women from the general population to assess the applicability of AI colposcopy in real-world cervical cancer screening, aiming to assess the performance of conventional, AI, and AI-assisted colposcopy among premenopausal and postmenopausal women, with further stratification by the seniority of the colposcopists and the status of the squamocolumnar junction.

METHODS

This cross-sectional, multicenter, observational study recruited 15,116 women for cervical cancer screening in Ganzi and Yanting counties, Sichuan Province, from March 2023 to May 2024. The inclusion criterion was as an anatomically intact cervix. Participants were required to understand the screening procedure, to voluntarily participate, and to provide written informed consent.

Cervical exfoliative cell samples were obtained for HPV testing and cytologic analysis. Women with positive HPV results or who were cytologic positive underwent colposcopy, during which AI colposcopy was implemented. A total of 825 women were finally included in the study. The study was approved by the ethics committees of the Chinese Academy of Medical Sciences and Peking Union Medical College (No. CAMS&PUMC-IEC-2022-059-1) and the Sichuan Cancer Hospital (No. SCCHEC-02-2023-047).

A gynecologist using disposable sampling kits to collect shed cervical cells performed HPV testing. Detection was conducted with next-generation hybridization capture technology, which can identify 14 high-risk HPV subtypes (16, 18, 31, 33, 35, 39, 45, 51, 52, 56, 58, 59, 66, and 68) and simultaneously differentiate types 16 and 18. The presence of any HPV type was classified as positive.

The cervical exfoliated cytology specimens collected by the gynecologist were preserved in PreservCyt solution, and cytologic smears were prepared within 1 week of sampling. Cytologic diagnostic results were interpreted according to the Bethesda 2014 classification system, which includes negative for intraepithelial lesion or malignancy, atypical squamous cells of undetermined significance (ASC-US), atypical squamous cells that cannot exclude high-grade squamous intraepithelial lesion (ASC-H), low-grade squamous intraepithelial lesion (LSIL), high-grade squamous intraepithelial lesion (HSIL), atypical glandular cells (AGC), squamous cell carcinoma (SCC), adenocarcinoma in situ (AIS), and adenocarcinoma. Findings of ASC-

US or worse (ASC-US+, including ASC-US, ASC-H, LSIL, HSIL, AGC, SCC, and AIS) were considered positive.

During conventional colposcopy, colposcopists applied 5% acetic acid or Lugol iodine to the cervix, recording the visibility of the squamocolumnar junction and colposcopic diagnostic results (negative–benign or positive: LSIL, HSIL, or cancer); both normal and benign results were considered negative. Biopsies were performed for positive findings. If the cytology indicated HSIL or worse (including HSIL, AGC, SCC, AIS) but the colposcopy was negative, random biopsies from the squamocolumnar junction and endocervical curettage would be performed. We used CAIADS along with conventional colposcopy. After staining, the AI colposcope captures images at 60, 90, 120, and 150 seconds according to conventional colposcopy. Using the cervical image recognition algorithm, CAIADS interprets colposcopic images and adjusts the initial recognition results from the image recognition algorithm according to the patient's previous cytologic and HPV test results, locating the cervical lesion areas, thereby optimizing the likelihood of diagnosis. Results of CAIADS are classified as positive or negative. A positive CAIADS result recommends a biopsy, and a negative result suggests follow-up. When CAIADS indicated biopsy, the clinicians re-examined the area indicated by the system and performed a biopsy on the corresponding region according to the actual situation. It should be noted that although the biopsy sites of the two methods may overlap, only one biopsy was performed to avoid redundant sampling. All patients underwent both conventional and AI-assisted colposcopy, with the two methods independent of each other. *Positive AI-assisted colposcopy* was defined as either a positive conventional colposcopy diagnosis or a negative conventional colposcopy diagnosis accompanied by a positive AI colposcopy diagnosis.

All pathologic slides were reviewed by pathologists from Sichuan Cancer Hospital. According to the pathologic diagnostic criteria for cervical epithelial tissue, cervical lesion diagnoses were classified as normal or inflammatory, CIN 1, CIN 2, CIN 3, and cancer (squamous cell carcinoma or adenocarcinoma). In clinical practice, CIN 2 is conventionally recognized as the screening end point for early detection and intervention. However, CIN 3+ (including CIN 3 and cancer) has a higher malignant potential and may progress to invasive cancer.[22] Therefore, we report both thresholds.

We have set the histopathologic diagnoses of CIN 2+ and CIN 3+ as the primary end points of this study. Categorical data were presented as counts and percentages, and continuous data reflecting age distributions were reported as medians with interquartile ranges. Sensitivity, specificity, positive predictive value, negative predictive value, area under the curve (AUC), κ, and agreement rate were calculated with epiR packages, along with 95% CIs, using the Wilson scoring method. Data were further stratified by menopausal status (*postmenopause* was defined as cessation of menstruation for 12 months or more), colposcopist seniority, and location of the squamocolumnar junction. In this study, *senior colposcopists* were defined as those with 10 years or more of clinical experience; those with less than 10 years of experience were defined as *junior*. The corresponding sensitivity, specificity, positive predictive value, negative predictive value, and AUCs were calculated for each subgroup. The paired χ^2 test was used to compare sensitivity and specificity among the AI colposcopy, AI-assisted colposcopy, and conventional colposcopy. $P<.05$ was considered statistically significant. Graphs were generated, and statistical analysis was performed with R 4.3.3.

RESULTS

A total of 825 women were included in the study (the detailed process of the included population is provided in Appendix 1, available at http://links.lww.com/AOG/E236), of whom 583 (70.7%) underwent biopsy. The median age of the participants was 53 years (interquartile range 47–57 years). Among them, 451 women (54.7%) were postmenopausal. Overall, 675 women (81.8%) tested positive for HPV infection, with 299 (36.2%) being positive for HPV 16/18. The squamocolumnar junction was completely visible in 245 women (29.7%) and not visible in 290 women (35.2%). Diagnoses revealed that 99 women (12.0%) had CIN 2+ and 53 women (6.4%) had CIN 3+. Detailed demographic information is presented in Table 1.

As shown in Table 2, conventional colposcopy identified 392 women as positive, with 85 pathologically confirmed as having CIN 2+ (21.7%); the other 433 women were negative under conventional colposcopy, and 14 of them were confirmed as having CIN 2+ (3.2%). Artificial intelligence colposcopy yielded 640 women as positive, and 95 of them were confirmed as having CIN 2+ (14.8%); 185 women were negative by AI colposcopy, of whom four were pathologically confirmed as CIN 2+ (2.2%).

The agreement between conventional colposcopy and AI colposcopy was 53.0% ($\kappa=0.085$, 95% CI, 0.029–0.140). The agreements between conventional

Table 1. Demographic Characteristics of the Study Population

Characteristic	n (%)
Age	53.0 (47.0, 57.0)
Age group (y)	
45 or younger	168 (20.3)
46–55	372 (45.1)
56 or older	285 (34.5)
Ethnic group	
Han	561 (68.0)*
Zang	261 (33.6)
Other	2 (0.2)
Marital status	
Single	93 (11.3)*
Married	696 (84.4)
Divorced	16 (1.9)
Widowed	19 (2.3)
Education	
Primary school or less	556 (67.4)*
Middle school	221 (26.8)
High school	33 (4.0)
Graduate	12 (1.5)
Occupation	
Unemployed	319 (38.7)*
Farmer	380 (46.1)
Worker	9 (1.1)
Enterprise personnel	40 (5.5)
Government employee	20 (2.4)
Other	51 (6.2)
Smoking status	
Never	815 (98.8)*
Former smoker	4 (0.5)
Current smoker	5 (0.6)
No. of pregnancies	
0 or 1	328 (39.8)*
2	335 (40.6)
3 or more	155 (18.9)
Menopausal status	
Premenopausal	369 (44.7)*
Postmenopausal	451 (54.7)
SCJ	
Completely visible	245 (29.7)*
Partially visible	248 (30.1)
Not visible	290 (35.2)
Biopsy	
No	242 (29.3)
Yes	583 (70.7)
Histopathology diagnosis	
Normal or inflammatory	656 (79.5)
CIN 1	70 (8.5)
CIN 2	46 (5.6)
CIN 3	52 (6.3)
Cancer	1 (0.1)
hrHPV infection	
Any hrHPV positive†	675 (81.8)
HPV 16/18	299 (36.2)
Negative	150 (18.2)

SCJ, squamocolumnar junction; CIN, cervical intraepithelial neoplasia; hrHPV, high-risk human papillomavirus.
Data are median (25th percentile, 75th percentile) or n (%).
* Missing values.
† Indicates a positive result for any one of the 14 high-risk HPV types (16, 18, 31, 33, 35, 39, 45, 51, 52, 56, 58, 59, 66, and 68) and is sufficient to be considered hrHPV positive.

colposcopy and histopathology and between AI colposcopy and histopathology were 65.8% (κ=0.296, 95% CI, 0.239–0.353) and 39.4% (κ=0.085, 95% CI, 0.050–0.120), respectively (Table 3).

As shown in Figure 1, conventional colposcopy demonstrated a sensitivity of 85.9% (95% CI, 77.1–91.8%), specificity of 57.7% (95% CI, 54.0–61.3%), and AUC of 0.718 (95% CI, 0.670–0.766). In contrast, AI colposcopy exhibited a sensitivity of 96.0% (95% CI, 89.4–98.7%), specificity of 24.9% (95% CI, 21.9–28.3%), and AUC of 0.604 (95% CI, 0.553–0.656). Furthermore, AI-assisted colposcopy achieved a sensitivity of 100% (95% CI, 95.3–100%), a specificity of 15.8% (95% CI, 13.3–18.7%), and an AUC of 0.579 (95% CI, 0.526–0.633). Both AI colposcopy and AI-assisted colposcopy demonstrated significantly higher sensitivity than conventional colposcopy (96.0% and 100% vs 85.9%, P=.026 and P<.001, respectively).

Among postmenopausal women, conventional colposcopy had a sensitivity of 77.4% (95% CI, 63.5–87.3%) and a specificity of 61.6% (95% CI, 56.6–66.3%). Artificial intelligence colposcopy showed a sensitivity of 94.3% (95% CI, 83.4–98.5%) and a specificity of 24.1% (95% CI, 20.1–28.7%). Artificial intelligence–assisted colposcopy achieved a sensitivity of 100% (95% CI, 91.6–100%) but had a specificity of 15.8% (95% CI, 12.5–19.9%). Both AI colposcopy and AI-assisted colposcopy demonstrated significantly higher sensitivity than conventional colposcopy (94.3% and 100% vs 77.4%, P=.026 and P<.001, respectively).

In examinations performed by junior colposcopists, conventional colposcopy detected CIN 2+ with a sensitivity of 84.6% (95% CI, 73.1–92.0%) and a specificity of 56.1% (95% CI, 51.3–60.9%). In this group, AI-assisted colposcopy achieved a sensitivity

Table 2. Histopathologic Diagnosis by Colposcopic Findings

Colposcopy Diagnosis	Total (n)	Histopathology Diagnosis					
		Normal or Inflammatory	CIN 1	CIN 2	CIN 3	CIN 2+	CIN 3+
Conventional colposcopy							
(−)	433	404 (93.3)	15 (3.5)	7 (1.6)	7 (1.6)	14 (3.2)	7 (1.6)
(+)	392	252 (64.3)	55 (14.0)	39 (9.9)	45 (11.5)	85 (21.7)	46 (11.7)
AI colposcopy							
(−)	185	171 (92.4)	10 (5.4)	3 (1.6)	1 (0.5)	4 (2.2)	1 (0.5)
(+)	640	485 (75.8)	60 (9.4)	43 (6.7)	51 (8.0)	95 (14.8)	52 (8.3)
Conventional colposcopy and AI colposcopy							
(+) and (−)*	70	58 (82.9)	8 (11.4)	3 (4.3)	1 (1.4)	4 (5.7)	1 (1.4)
(−) and (+)†	318	291 (91.5)	13 (4.1)	7 (2.2)	7 (2.2)	14 (4.4)	7 (2.2)
(+) and (+)‡	322	194 (60.2)	47 (14.6)	36 (11.2)	44 (13.7)	81 (25.2)	45 (14.0)
(−) and (−)§	115	113 (98.3)	2 (1.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

CIN, cervical intraepithelial neoplasia; AI, artificial intelligence.
Data are n (%) unless otherwise specified.
* Conventional colposcopy positive and AI colposcopy negative.
† Conventional colposcopy negative and AI colposcopy positive.
‡ Conventional colposcopy positive and AI colposcopy positive.
§ Conventional colposcopy negative and AI colposcopy negative.

of 100% (95% CI, 93.0–100%) with a specificity of 12.5% (95% CI, 9.6–16.1%). Artificial intelligence–assisted colposcopy significantly outperformed conventional colposcopy in sensitivity (100% vs 84.6%, P=.001).

When the squamocolumnar junction was not visible, conventional colposcopy exhibited a sensitivity of 70.4% (95% CI, 49.6–85.5%) and a specificity of 66.2% (95% CI, 50.1–71.8%). In contrast, AI-assisted colposcopy demonstrated a sensitivity of 100% (95% CI, 84.5–100%) but had a specificity of only 17.5% (95% CI, 13.2–22.7%). The sensitivity of AI-assisted colposcopy was significantly greater than that of conventional colposcopy (100% vs 70.4%, P=.004).

For the detection of CIN 3+, conventional colposcopy had a sensitivity of 86.8% (95% CI, 74.1–94.1%) and a specificity of 55.2% (95% CI, 51.6–58.7%). On the other hand, AI-assisted colposcopy demonstrated a sensitivity of 100% (95% CI, 91.6–100%) and a specificity of 19.1% (95% CI, 16.5–22.0%). The sensitivity of AI-assisted colposcopy was significantly higher than that of conventional colposcopy (100% vs 86.8%, P=.013).

In postmenopausal women, conventional colposcopy showed a sensitivity of 77.8% (95% CI, 57.3–90.6%) and a specificity of 59.2% (95% CI, 54.3–63.9%). Artificial intelligence colposcopy had a sensitivity of 100% (95% CI, 84.5–100%) and a specificity of 23.4% (95% CI, 19.5–27.7%). Artificial intelligence–assisted colposcopy demonstrated a sensitivity of 100% (95% CI, 91.6–100%) and specificity of 14.9% (95% CI, 11.7–18.7%). Both AI colposcopy and AI-assisted colposcopy were significantly more sensitive than conventional colposcopy in detecting CIN 3+ (100% and 100% vs 77.8%, P=.023). These findings are illustrated in Figure 2.

DISCUSSION

This study demonstrates that AI colposcopy offers advantages in assisting conventional colposcopy for detecting precancerous cervical lesions in low-resource settings, especially among postmenopausal women and those with a squamocolumnar junction that was not visible. Artificial intelligence–assisted colposcopy outperforms conventional methods in identifying CIN 2+, thus enhancing the diagnostic capabilities of less experienced colposcopists. Although the specificity of AI-assisted colposcopy is relatively low, it is important to note that all referrals for colposcopy come from individuals at high risk with positive initial screenings. Missed diagnoses in this context could pose considerable clinical risks. Therefore, sensitivity was prioritized as the primary focus to ensure the identification of patients with potential lesions.

Colposcopy is crucial for cervical cancer screening, but its effectiveness is constrained by colposcopists' subjective clinical experience, resulting in inconsistencies. Moreover, the shortage of skilled colposcopists, especially in low-resource settings, poses significant challenges; training qualified professionals demands substantial manpower, materials, and financial resources. Advancements in AI have enabled the

Table 3. Consistency Among Conventional Colposcopy, Artificial Intelligence Colposcopy, and Histopathology Diagnosis Across Different Populations

	Conventional Colposcopy		AI Colposcopy		Histopathology Diagnosis	
Colposcopy	κ (95% CI)	Agreement Rate (%)	κ (95% CI)	Agreement Rate (%)	κ (95% CI)	Agreement Rate (%)
Overall						
Conventional	—	—	0.085 (0.029–0.140)	53.0 (49.6–56.4)	0.296 (0.239–0.353)	65.8 (62.5–69.1)
AI	0.085 (0.029–0.140)	53.0 (49.6–56.4)	—	—	0.085 (0.050–0.120)	39.4 (36.0–42.8)
Postmenopausal						
Conventional	—	—	0.054 (−0.016–0.124)	49.0 (44.4–53.6)	0.279 (0.199–0.359)	67.0 (62.4–71.3)
AI	0.054 (−0.016–0.124)	49.0 (44.4–53.6)	—	—	0.066 (0.020–0.112)	37.7 (33.2–42.3)
Premenopausal						
Conventional	—	—	0.125 (0.036– 0.214)	57.7 (52.7–62.8)	0.309 (0.229–0.390)	64.2 (59.1–69.1)
AI	0.125 (0.036–0.214)	57.7 (52.7–62.8)	—	—	0.107 (0.054–0.161)	41.5 (36.4–46.7)
SCJ						
Completely visible						
Conventional	—	—	0.077 (−0.023–0.176)	52.2 (46.0–58.5)	0.077 (−0.023–0.176)	69.8 (63.6–75.5)
AI	0.077 (−0.023–0.176)	52.2 (46.0–58.5)	—	—	0.087 (0.027–0.147)	38.4 (32.2–44.8)
Partially visible						
Conventional	—	—	0.115 (0.004–0.226)	58.9 (52.7–65.0)	0.181 (0.087–0.246)	56.0 (49.6–62.3)
AI	0.115 (0.004–0.226)	58.9 (52.7–65.0)	—	—	0.135 (0.070–0.200)	43.1 (36-9–49.6)
Not visible						
Conventional	—	—	0.040 (−0.043–0.123)	45.5 (39.8–51.2)	0.304 (0.200–0.407)	70.7 (65.1–75.9)
AI	0.040 (−0.043–0.123)	45.5 (39.8–51.2)	—	—	0.030 (−0.027–0.088)	35.5 (30.0–41.3)
Clinician level						
Senior colposcopist						
Conventional	—	—	0.096 (0.002–0.189)	52.9 (47.5–58.3)	0.240 (0.160–0.320)	64.7 (59.3–69.9)
AI	0.096 (0.002–0.189)	52.9 (47.5–58.3)	—	—	0.098 (0.045–0.150)	41.3 (36.0–46.9)
Junior colposcopist						
Conventional	—	—	0.070 (0.003–0.137)	53.0 (48.6–57.4)	0.325 (0.248–0.402)	66.5 (62.2–70.7)
AI	0.070 (0.003–0.137)	53.0 (48.6–57.4)	—	—	0.063 (0.018–0.107)	38.1 (33.8–42.5)

AI, artificial intelligence; SCJ, squamocolumnar junction.

development of AI colposcopy systems that leverage deep learning to improve diagnostic precision and efficiency.[17] In addition, the real-time analysis capabilities of AI allow clinicians to obtain diagnostic results swiftly, which in turn expedite treatment decisions.[23]

Both Xue et al[13] and Zhao et al[14] reported that AI or AI-assisted colposcopy had higher sensitivity than colposcopists for detecting CIN 2+. In our study, we assessed CAIADS for detecting CIN 2+ in real-world scenarios. Both AI colposcopy (96.0 vs 85.9, $P=.026$) and AI-assisted colposcopy (100 vs 85.9, $P<.001$) significantly improved the sensitivity for detecting CIN 2+. This finding, highly consistent with the previous research by Xue et al and Zhao et al, strongly demonstrates that AI colposcopy has a very low rate of

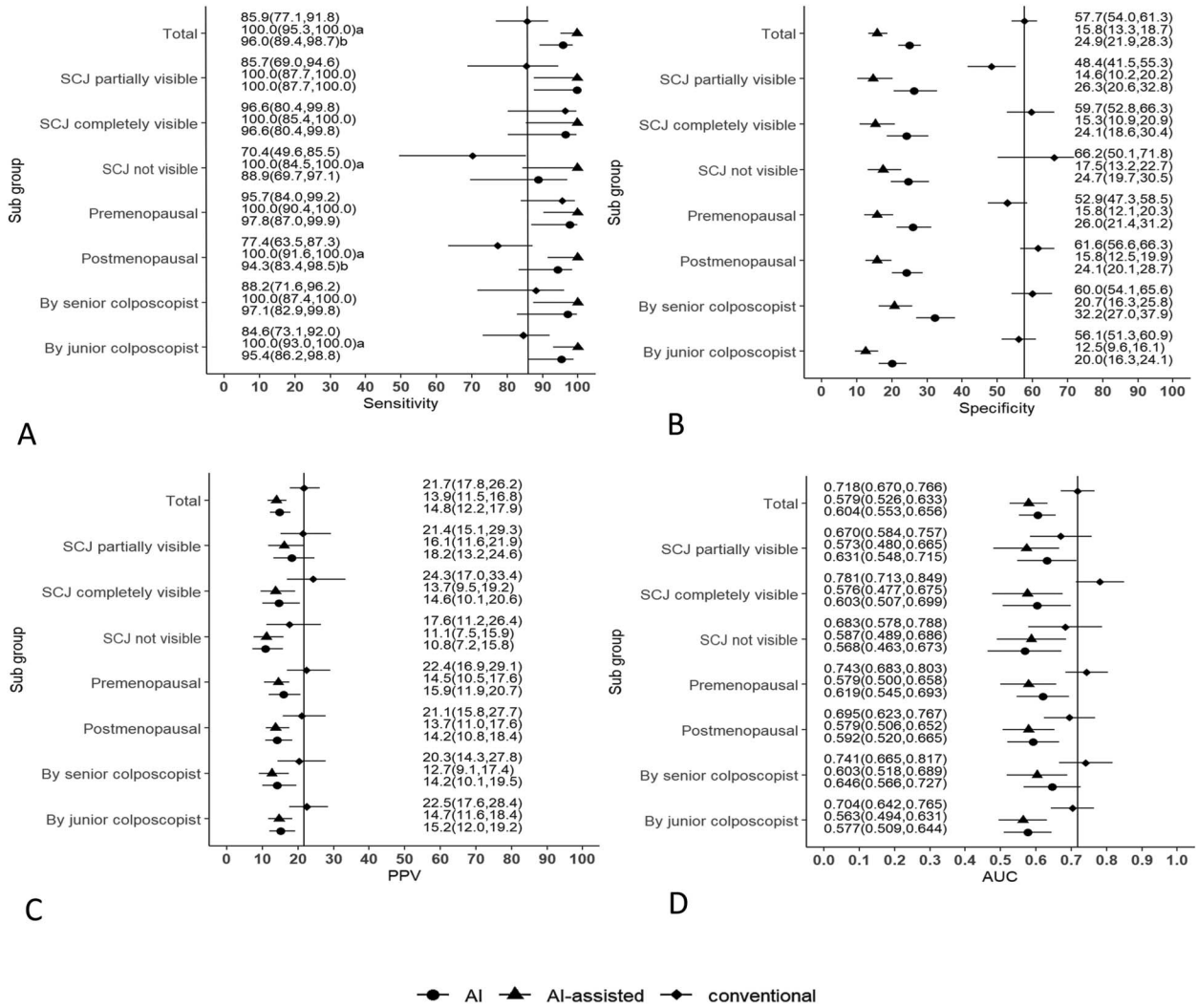

Fig. 1. Clinical accuracy of conventional colposcopy, artificial intelligence (AI) colposcopy, and AI-assisted colposcopy in detecting cervical intraepithelial neoplasia (CIN) 2+ among different women. Sensitivity (**A**), specificity (**B**), positive predictive value (PPV) (**C**), and area under the curve (AUC) (**D**). SCJ, squamocolumnar junction. [a]Statistical significance in sensitivity between AI-assisted colposcopy and traditional colposcopy ($P<.05$). [b]Statistical significance in sensitivity between AI colposcopy and traditional colposcopy ($P<.05$).

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missed diagnoses in low-resource settings and can maximize the detection of CIN 2+ cases. Although the AI systems used in the studies by Kim et al[24] and Mascarenhas et al[11] differ from the one we used, their results similarly demonstrate that both AI-assisted colposcopy and AI colposcopy can effectively increase the detection rate of cervical precancerous lesions.

However, the accuracy of targeted biopsies under colposcopy is influenced by multiple factors, including age, menopausal status, squamocolumnar junction location, and colposcopist experience.[15,25] These variables contribute to heterogeneity, affecting the generalizability of study findings. To address this, we stratified our analysis by menopausal status, squamocolumnar junction location, and colposcopist experience to gain a clearer understanding of where AI colposcopy outperforms conventional methods. First, we found that the κ values of AI colposcopy and traditional colposcopy compared with pathologic results in postmenopausal women were lower than those in premenopausal women, indicating that menopausal status affects colposcopic detection. Fan et al[25] also reported that postmenopausal status might be

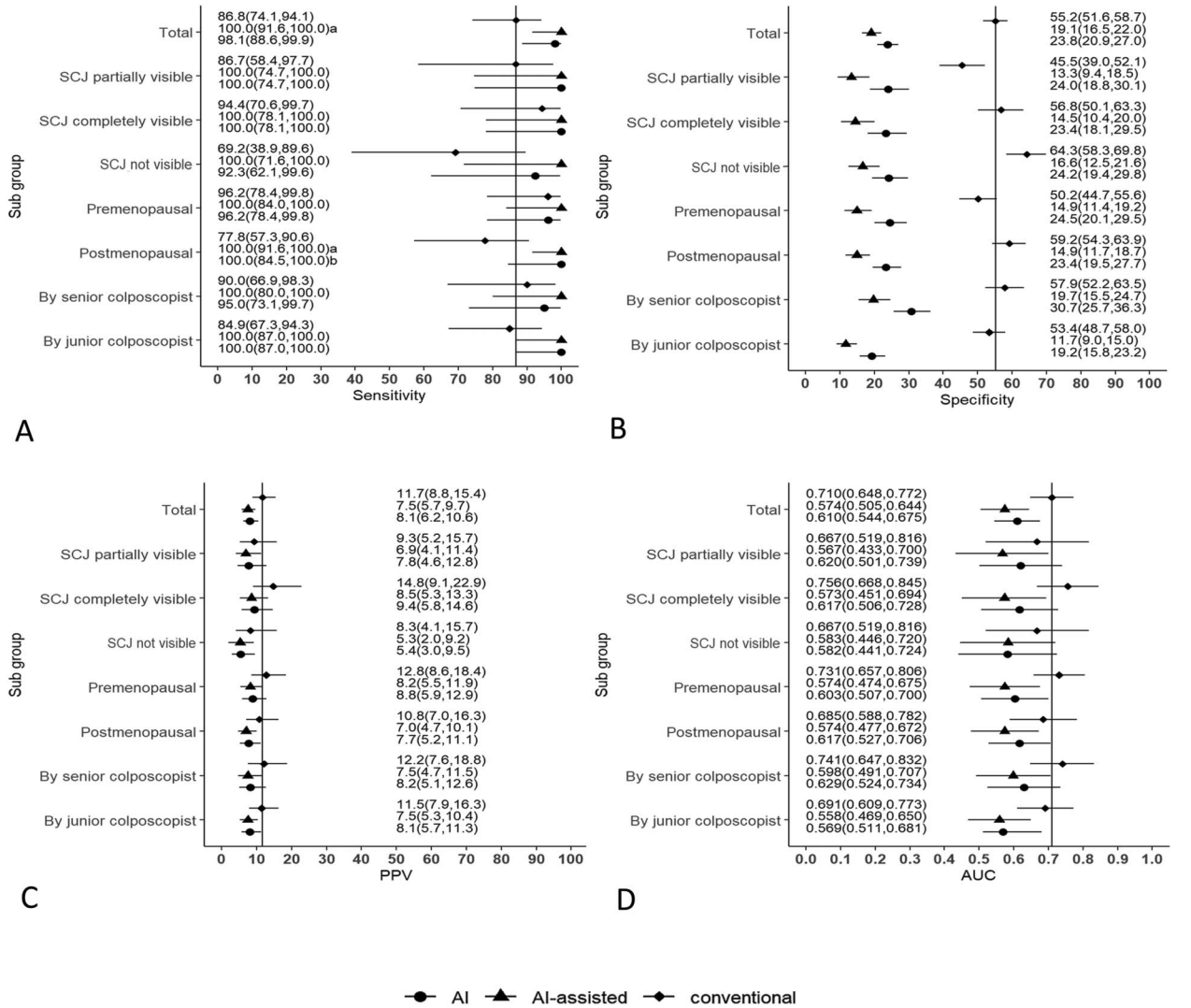

Fig. 2. Clinical accuracy of conventional colposcopy, artificial intelligence (AI) colposcopy, and AI-assisted colposcopy in detecting cervical intraepithelial neoplasia (CIN) 3+ among different women. Sensitivity (**A**), specificity (**B**), positive predictive value (PPV) (**C**), and area under the curve (AUC) (**D**). [a]Statistical significance in sensitivity between AI-assisted colposcopy and traditional colposcopy ($P<.05$); [b]Statistical significance in sensitivity between AI colposcopy and traditional colposcopy ($P<.05$). SCJ, squamocolumnar junction.

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positively associated with underdiagnosis of colposcopically directed biopsy (odd ratio 0.104, $P=.018$). As previously noted, we found that AI colposcopy and AI-assisted colposcopy showed significantly higher sensitivity in detecting CIN 2+ and CIN 3+ in postmenopausal women compared with conventional colposcopy (all $P<.05$). Furthermore, the lack of visibility of squamocolumnar junction increases the difficulty in diagnosing cervical precancerous lesions.[26] Our study revealed that AI-assisted colposcopy notably enhanced the sensitivity for detecting CIN 2+ (100% vs 70.4%, $P=.004$) when the squamocolumnar junction was not visible. In addition, differences in colposcopist expertise affect the accuracy of detecting cervical precancerous lesions. We found that AI-assisted colposcopy increased junior colposcopists' sensitivity for detecting CIN 2+ from 83.3% to 98.5%. Similar to our findings, Wu et al[21] reported that the CAIADS increased the sensitivity of junior colposcopists for detecting CIN 2+ from 79.6% to 95.1%. Overall, these studies highlight the promising potential of AI-assisted colposcopy in improving

clinical outcomes for detecting precancerous lesions in low-resource settings.

However, in our study, the κ value and the specificity of the AI and conventional colposcopy compared with the pathologic diagnosis results were both low. Our findings are inconsistent with those of Xue et al[13] (AI, κ=0.750; conventional, κ=0.516), which may stem from the facts that their study population was hospital based and that individuals with CIN 2+ accounted for 38.5% (5,237/13,604) of the total enrolled population; in our enrolled general population cohort, the proportion of those with CIN 2+ was 12.1% (100/825). The lower CIN 2+ prevalence in our study likely reduced the specificity and κ values of AI colposcopy. The Zhao et al[14] study, which included 346 hospital patients, had a CIN 2+ rate of 25.7% (89/346), with a higher CIN 2+ prevalence than our study but lower than in the Xue et al study. We found that AI colposcopy in the Zhao et al study showed CIN 2+ specificity higher than ours (57.6% vs 24.9%) but lower than that in the Xue et al study (57.6% vs 93.3%), with similar trends in AI-assisted specificity (38.1% vs 13.3%). These variations likely reflect potential bias in AI colposcopy, influenced by differing CIN 2+ prevalences across cohorts. Our study focuses on AI colposcopy for cervical precancer detection in general populations in resource-constrained settings, prioritizing missed diagnosis avoidance. The results consistently show that AI colposcopy and AI-assisted methods significantly improve CIN 2+ detection rates. Notably, low-prevalence scenarios may increase the false-positive rate of AI, leading to more biopsies. Future AI system updates should optimize screening efficacy for general populations in low-resource settings to reduce false-positives.

The strengths of this study lie in comparing the accuracy of AI-assisted colposcopy between postmenopausal and premenopausal women in low-resource settings and evaluating various squamocolumnar junction states. Such analyses facilitate the identification of specific clinical scenarios in which AI colposcopy shows advantages, offering valuable evidence to inform clinical practice.

However, our study has several limitations. First, the low number of CIN 2+ cases resulted in low κ values and specificity in our study. Future research should include data from more centers. Second, not all women underwent biopsy, limiting our ability to resolve discrepancies between AI colposcopy and clinician assessments regarding the necessity for biopsy. In our study, women with negative colposcopic findings did not undergo biopsy, which may have resulted in missed diagnoses and an overestimation of the sensitivities, although the risk is low. In a previous study, women with negative colposcopic results underwent randomized biopsies, yielding a CIN 2+ detection rate of 0.02.[27] Follow-up of the enrolled women in the future could enable us to identify the overestimation and to evaluate the long risk of CIN 2+ of different colposcopic findings under AI-assisted colposcopy.

Our study implies that AI colposcopy offers advantages in assisting conventional colposcopy for detecting high-grade precancerous cervical lesions, especially among postmenopausal women and those with a squamocolumnar junction that is not visible. Artificial intelligence–assisted colposcopy outperforms conventional methods in identifying CIN 2+, thus enhancing the diagnostic capabilities of less experienced colposcopists. In regions with limited health care resources and a shortage of experienced colposcopists,[28] AI colposcopy can serve as a valuable tool to enhance clinical practice and to aid decision making in cervical cancer screening.

REFERENCES

1. Arbyn M, Weiderpass E, Bruni L, de Sanjosé S, Saraiya M, Ferlay J, et al. Estimates of incidence and mortality of cervical cancer in 2018: a worldwide analysis. Lancet Glob Health 2020; 8:e191–203. doi: 10.1016/S2214-109X(19)30482-6
2. Han B, Zheng R, Zeng H, Wang S, Sun K, Chen R, et al. Cancer incidence and mortality in China, 2022. J Natl Cancer Cent 2024;4:47–53. doi: 10.1016/j.jncc.2024.01.006
3. Sun K, Han B, Zeng H, Wang S, Li L, Chen R, et al. Incidence and mortality of cancers in female genital organs–China, 2022. China CDC Wkly 2024;6:195–202. doi: 10.46234/ccdcw2024.040
4. de Sanjosé S, Brotons M, Pavón MA. The natural history of human papillomavirus infection. Best Pract Res Clin Obstet Gynaecol 2018;47:2–13. doi: 10.1016/j.bpobgyn.2017.08.015
5. Alfonzo E, Zhang C, Daneshpip F, Strander B. Accuracy of colposcopy in the Swedish screening program. Acta Obstet Gynecol Scand 2023;102:549–55. doi: 10.1111/aogs.14538
6. Li X, Zhao Y, Xiang F, Zhang X, Chen Z, Zhang M, et al. Evaluation of the diagnostic performance of colposcopy in the detection of cervical high-grade squamous intraepithelial lesions among women with transformation zone type 3. BMC Cancer 2024;24:381. doi: 10.1186/s12885-024-12156-2
7. Benkortbi K, Catarino R, Wisniak A, Kenfack B, Tincho Foguem E, Venegas G, et al. Inter- and intra-observer agreement in the assessment of the cervical transformation zone (TZ) by visual inspection with acetic acid (VIA) and its implications for a screen and treat approach: a reliability study. BMC Womens Health 2023;23:27. doi: 10.1186/s12905-022-02131-z
8. Qin D, Bai A, Xue P, Seery S, Wang J, Mendez MJG, et al. Colposcopic accuracy in diagnosing squamous intraepithelial lesions: a systematic review and meta-analysis of the International Federation of Cervical Pathology and Colposcopy 2011 terminology. BMC Cancer 2023;23:187. doi: 10.1186/s12885-023-10648-1

9. Akazawa M, Hashimoto K. Artificial intelligence in gynecologic cancers: current status and future challenges–a systematic review. Artif Intell Med 2021;120:102164. doi: 10.1016/j.artmed.2021.102164

10. Mendez MJG, Xue P, Qiao YL. Cervical cancer elimination in the era of COVID-19: the potential role of artificial intelligence (AI)-guided digital colposcope cloud platform. Eur J Gynaecol Oncol 2022;43:160–2. doi: 10.31083/j.ejgo4301019

11. Mascarenhas M, Alencoão I, Carinhas MJ, Martins M, Cardoso P, Mendes F, et al. Artificial intelligence and colposcopy: automatic identification of cervical squamous cell carcinoma precursors. J Clin Med 2024;13:3003. doi: 10.3390/jcm13103003

12. Gupta R, Kumar N, Bansal S, Singh S, Sood N, Gupta S. Artificial intelligence-driven digital cytology-based cervical cancer screening: is the time ripe to adopt this disruptive technology in resource-constrained settings? A literature review. J Digit Imaging 2023;36:1643–52. doi: 10.1007/s10278-023-00821-0

13. Xue P, Tang C, Li Q, Li Y, Shen Y, Zhao Y, et al. Development and validation of an artificial intelligence system for grading colposcopic impressions and guiding biopsies. BMC Med 2020;18:406. doi: 10.1186/s12916-020-01860-y

14. Zhao Y, Li Y, Xing L, Lei H, Chen D, Tang C, et al. The performance of artificial intelligence in cervical colposcopy: a retrospective data analysis. J Oncol 2022;2022:4370851. doi: 10.1155/2022/4370851

15. McGee AE, Alibegashvili T, Elfgren K, Frey B, Grigore M, Heinonen A, et al. European consensus statement on expert colposcopy. Eur J Obstet Gynecol Reprod Biol 2023;290:27–37. doi: 10.1016/j.ejogrb.2023.08.369

16. Xue P, Ng MTA, Qiao Y. The challenges of colposcopy for cervical cancer screening in LMICs and solutions by artificial intelligence. BMC Med 2020;18:169. doi: 10.1186/s12916-020-01613-x

17. Gallay C, Girardet A, Viviano M, Catarino R, Benski AC, Tran PL, et al. Cervical cancer screening in low-resource settings: a smartphone image application as an alternative to colposcopy. Int J Womens Health 2017;9:455–61. doi: 10.2147/IJWH.S136351

18. Viñals R, Jonnalagedda M, Petignat P, Thiran JP, Vassilakos P. Artificial intelligence-based cervical cancer screening on images taken during visual inspection with acetic acid: a systematic review. Diagnostics (Basel) 2023;13:836. doi: 10.3390/diagnostics13050836

19. Hamamoto R. Application of artificial intelligence for medical research. Biomolecules 2021;11:90. doi: 10.3390/biom11010090

20. Briganti G, Le Moine O. Artificial intelligence in medicine: today and tomorrow. Front Med 2020;7:27. doi: 10.3389/fmed.2020.00027

21. Wu A, Xue P, Abulizi G, Tuerxun D, Rezhake R, Qiao Y. Artificial intelligence in colposcopic examination: a promising tool to assist junior colposcopists. Front Med (Lausanne) 2023;10:1060451. doi: 10.3389/fmed.2023.1060451

22. Fontham ETH, Wolf AMD, Church TR, Etzioni R, Flowers CR, Herzig A, et al. Cervical cancer screening for individuals at average risk: 2020 guideline update from the American Cancer Society. CA Cancer J Clin 2020;70:321–46. doi: 10.3322/caac.21628

23. Vadhwana B, Tarazi M, Patel V. The role of artificial intelligence in prospective real-time histological prediction of colorectal lesions during colonoscopy: a systematic review and meta-analysis. Diagnostics (Basel) 2023;13:3267. doi: 10.3390/diagnostics13203267

24. Kim S, Lee H, Lee S, Song JY, Lee JK, Lee NW. Role of artificial intelligence interpretation of colposcopic images in cervical cancer screening. Healthcare (Basel) 2022;10:468. doi: 10.3390/healthcare10030468

25. Fan A, Zhang L, Wang C, Wang Y, Han C, Xue F. Analysis of clinical factors correlated with the accuracy of colposcopically directed biopsy. Arch Gynecol Obstet 2017;296:965–72. doi: 10.1007/s00404-017-4500-z

26. Desai KT, Hansen N, Rodriguez AC, Befano B, Egemen D, Gage JC, et al. Squamocolumnar junction visibility, age, and implications for cervical cancer screening programs. Prev Med 2024;180:107881. doi: 10.1016/j.ypmed.2024.107881

27. Zhao Y, Zhao F, Hu S, Zhang X, Zhang W, Pan Q, et al. Value of multi-quadrants biopsy: pooled analysis of 11 population-based cervical cancer screening studies. Chin J Cancer Res 2020;32:383–94. doi: 10.21147/j.issn.1000-9604.2020.03.09

28. Brodeur TY, Grow D, Esfandiari N. Access to fertility care in geographically underserved populations, a second look. Reprod Sci 2022;29:1983–7. doi: 10.1007/s43032-022-00991-2

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