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A multimodal deep learning model for cervical pre-cancers and cancers prediction: Development and internal validation study

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ABSTRACT

Background: The current cervical cancer screening and diagnosis have limitations due to their subjectivity and lack of reproducibility. We describe the development of a deep learning (DL)-based diagnostic risk prediction model and evaluate its potential for clinical impact.

Method: We developed and internally validated a DL model which accommodates both clinical data and colposcopy images in predicting the patients CIN2+ status using a retrospective cohort of 6356 cases of LEEP-conization/cone-biopsy (gold-standard diagnosis) following an abnormal screening result. The overall performance, discrimination, and calibration of the model were compared to expert clinician's colposcopic impression. The potential for clinical impact was assessed with rate of unnecessary conizations that could be avoided by using our model.

Results: The model combining clinical history and colposcopy images demonstrated superior performance prediction of CIN2+(AUC-ROC = 95.3 %, accuracy = 90.8 %, PPV = 94.1 %, NPV = 87.9 %) and better calibration compared to models that used image or clinical history data alone and outperformed clinician's colposcopic impressions. Moreover, if a decision threshold of 10 % is applied to the predicted probability from this model to recommend conization, up to 35 % of conizations could be avoided without missing any true CIN2+ cases.

Conclusion: We present a novel DL model to predict cervical neoplasia with potential for reducing unnecessary conization. External validation studies are warranted for assessing generalizability.

1. Introduction

Cervical cancer remains a major contributor to female cancer incidence and morbidity worldwide [1–4]. Despite the advances in screening and diagnostic techniques, many cases still evade early detection and appropriate management [5–7].

Current recommendations for screening and diagnosis of cervical precancers and cancers include several procedures including Human Papillomavirus (HPV) testing, cytology triage, colposcopy, punch biopsy, endocervical curettage, cone biopsy and histopathological examination [8]. Nevertheless, despite the historical success of cytology, colposcopy, and histology in screening and diagnosis, these methods are not devoid of limitations [6,9,10]. The reliance on human visual assessment results in significant inter- and intra-observer variability, leading to suboptimal sensitivity and specificity [11–14]. For example, approximately 14 % of invasive cervical cancers are observed after inappropriate colposcopy management, and 9 % after a delay in care of more than 3 months following an abnormal colposcopy screening [6]. Moreover, sensitivity of colposcopy for high grade cervical intraepithelial neoplasia (HG-CIN) lesions is estimated to be between 50 % and 70 % and specificity lower than 50 % [14–16].

The reliability of punch biopsies also raises concern, with challenges in recognizing and localizing severe lesions, particularly when the squamocolumnar junction (SCJ) is not visible [9,16]. Histological analysis suffers similar fates of poor reproducibility and variability, especially when distinguishing between metaplasia and different grades of CIN [17,18]. The concordance between colposcopic impression and histological findings is less than optimal, estimated at under 65 % [9,19,20].

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