Chapter

The Role of AI in Cervical Cancer Screening

Bojana Turic, Xiaorong Sun, Jian Wang and Baochang Pang

Abstract

In the last few years internet-based technologies played an important role in reinventing various medical procedures and facilitating quick access to medical services and care, particularly in the remote areas of China. The use of artificial intelligence and cloud computing in clinical laboratory setting for slide analysis contributed to standardized cytology and pathology diagnosis but more importantly slide analysis with artificial intelligence has a huge potential to compensate for a country wide lack of pathologists and systematic quality control. While well-established automated slide scanning is already in use, we added intelligent algorithms located in a secure cloud for the better slide readings, and mobile phone microscopes to capture those regions of Hubei province where laboratory infrastructure is supported by high-speed internet and 5G networks. These technological advances allowed us to bring an important pathology expertise across the large areas of China.

Keywords: cervical cancer screening, artificial intelligence, cloud computing

1. Introduction

The contemporary artificial intelligence techniques such as machine learning applications were widely used in medicine and achieved the substantial success, particularly in radiology, in the recent years [1, 2]. Most of the technologies to support AI in pathology are still in development phase or are at the state of an observational study [3]. They are not widely applied in a large-scale screening as a routine service. This chapter will explain why and how AI and cloud computing is deployed as a standard of care in Province of Hubei, China and will illustrate all advantages that artificial intelligence can add making cervical cancer screening efficient and economically sound. This model can be easily adapted anywhere in the world where cytology is the only method or is combined with HPV in the cervical cancer screening.

2. Cervical cancer in China

In December 2020 China's National Health Commission (NHC) has voiced full support for the "Global Strategy to Accelerate the Elimination of Cervical Cancer" launched by the World Health Organization (WHO). According to data from 2018 cervical cancer is the fourth most frequent malignant tumor in women [4]. The same report shows that there were approximately 570000 cases of cervical cancer with estimated 310000 deaths globally. Peking University Health Care Center published that after 2000, the incidence of cervical cancer in China is on the rise while the mortality rate stayed somewhat the same. In 2015 the number of newly diagnosed cervical cancer cases was 98900 and the number of deaths reached 30500. However, in 2018 the reported number of cases were 106000 with 48000 deaths, which shows that the cervical cancer is indeed on the rise. That is particularly true for the women in rural areas. Since 2009, Chinese health authorities initiated free large-scale population-based cervical cancer screening for rural women with low socioeconomic status totaling approximately 10 million people [5]. These early initiatives were important and laid the foundation for cervical cytology screening guideline development in China. It is fair to say that these early initiatives were also important for bringing awareness about the importance of cervical examination among women.

3. How cervical cancer screening methodology was introduced?

Detecting cervical precancerous lesions and implementing early screening followed by early treatment intervention are proven essential steps in prevention and treatment of cervical cancer. Decrease in cervical cancer incidence in most western countries can be attributed to the success of screening using the Papanicolaou test (PAP-test) where this method has proved to effectively reduce cervical cancer incidence and mortality [6, 7]. PAP-test is based on detecting cellular changes that can progress into malignant changes but if detected at an early stage can be treated and prevent development of cervical cancer. It has been shown in many countries around the world that implementing PAP-test in systematic, comprehensive screening programs can reduce incidence of cervical cancer. In recent years, HPV-DNA virus examination methods have also been introduced into cervical cancer screening [8]. The success and program implementation differ among countries and so in China too, in certain areas it is introduced with questionable success. In the western countries for example in Canada and Japan, more traditional cytology analysis methods are still used [9], while UK, USA and Australia use HPV detection methods [10–12].

4. Why is AI and cloud computing the best approach for mass screening?

Due to China's huge and growing population, a simple "mirror" of the European or American guidelines for cervical screening is not possible due to several major differences in the medical system organization: (1) In China, the primary point of sample collection is not a family physician office setting like in the most of the western countries, but gynecologist, or specially trained nurse (2) There is an insufficient number of laboratory professionals, particularly cytotechnicians to screen, read the slides and issue negative reports and (3) Organized quality control and assurance is not established nationwide and it varies from laboratory to laboratory. The lack of cytotechicians and cytopathologists in county's and town's level medical institutions make cervical cancer screening uneven thus in many places, the purpose of screening is lost [13].

In the recent years we saw rapid development in deep learning and artificial intelligence technologies. The intelligent recognition of medical images and counting method of deep learning has made possible the use of the artificial intelligence (AI) in diagnostic techniques such as X-ray, CT, mammography and pathology [14–17]. With the data quality and improvements of speed in automated microscopes and whole slide scanners [18], telepathology was introduced as a first step for remote slide interpretation [19]. The adoption was slow however today telepathology is an integral part of almost every pathology laboratory particularly for second opinion. It was logical that the next technological development, the use of artificial intelligence in laboratory medicine came after years of research and systems training with millions of cervical specimens.

The first AI diagnostic techniques for use in a large-scale cervical cancer screening in primary hospitals without cytopathologists was implemented in Hubei province, China. It allowed diagnosis without physical transportation of samples (slides); data are analyzed in the cloud at the very high speed. When AI was introduced (2017) it greatly reduced the financial, time cost and improved the accessibility of expert pathologist and fast turnaround for cytology results to patients [20]. These were the first steps towards today's use of AI for slide scanning and robotic data analysis. Furthermore, today we do not even need the fully developed scanner, the new mobile phone microscopes particularly in the remote and rural areas are used and are already improving the way cervical cancer screening is delivered.

5. The start of AI and cloud computing in cervical cancer screening, Hubei Province, China

In 2017, Hubei's Provincial Health Authority authorized a cervical cancer screening program that used a unique cloud-based platform for cervical cancer screening, data gathering, analysis, review and reporting to provide screening services to rural women in the province. The project was authorized by Ethic Review Board who agreed to approve the project. Data were continuously collected and presented for a final authorization to use AI as a standard in a cervical cancer screening.

From January 1, 2018 to December 31, 2018, a total of 703,103 women were screened for cervical cancer and those data are published recently (**Figure 1**). The vast majority were women between 30 and 65 years of age. Out of the total number of women 30,035 (4.3%) were between the ages of 20 and 30, and 8,313 (1.2%) were over 65 years of age. All women were of low socioeconomic status and from 83 counties in China's Hubei Province. As mentioned earlier the objective of the program was to assess the feasibility of a cloud-based screening program and the management of healthcare statistics.

Without going into too many details, which are published elsewhere [21], our study showed high agreement rate for normal cytology grade between AI and manual reading. We showed that well-"trained AI system" can accurately classify normal cytology. In our case more than 99% of women classified as normal cytology by AI were confirmed by manual reading, suggesting that most of women with normal cytology could be primarily excluded by AI. In other words, AI system identified majority of slides most likely to be normal as only needing rapid review. This was a very important finding for laboratories that handle over 1 million slides in a short period.

AI-assisted cytology showed increased sensitivity without substantial decrease in specificity for detection of CIN2+, compared with manual reading, in accordant with previous observational studies using automated cytology [18, 19]. In our study, the detection of histological CIN2+ among women classified as normal by manual reading and abnormal by AI, was substantially higher than that among women classified as normal by AI and abnormal by manual reading. The detection of CIN2+ in our study was higher than the national program (155 versus 125 per 100 000), which can perhaps be explained because all women were from rural areas whose incidence is higher than countries average.

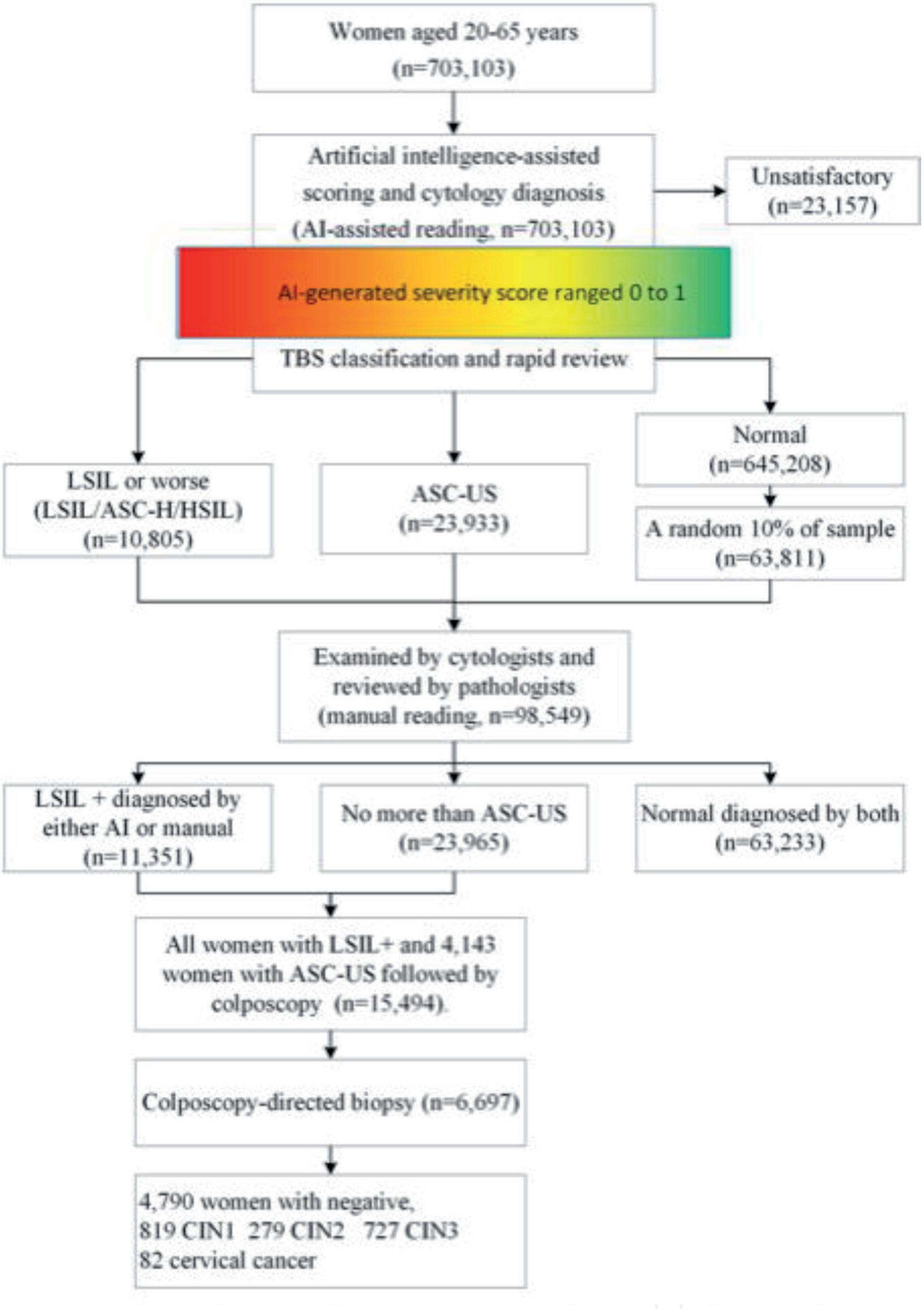

Figure 1.
The main study flow and the points at which data were collected.

An important issue of cytology-based cervical cancer screening is the management of women with ASC-US, in which detection of high-grade lesions or cancer varies greatly. Inappropriate triage may result in an over referral of colposcopy, or a delayed diagnosis and treatment. Although human papillomavirus test, genotyping or some biomarkers (e.g. methylation, p16/Ki-67) provide technology for triaging ASC-US, these algorithms are very limited in low-resource settings.

AI-assisted cytology system provides opportunities to address many difficulties that cervical cancer screening in China is facing. In the mode of AI-assisted cytology-based cervical cancer screening, large number of slides are automatically scanned and transferred to electronic cytology images and classified by pre-trained deep learning algorithms. For example, our laboratory received over 2 million slides in 2019. Although the system is automated each abnormal (positive) slide is still reviewed by cytologists who can log in into the cloud and review remotely and randomly selected 10% negative for quality control purposes.

Although the performance of automated-assisted cytology reading as a primary screening was reported previously [22] to our best knowledge, our study was the largest scale population-based cervical cancer screening using AI-assisted cytology reading in the low- and middle-income countries followed by AI routine implementation for cervical cancer screening. Once data were presented to our health authorities, we were allowed to offer cervical cancer screening based on AI as a routine clinical service.

6. Current implementation

Landing complete AI system has three major key components: an automated slide scanner installed in laboratories of counites hospitals, data uploading, and cloud platform for data processing and storing. The cloud system also connects to end users (physicians and patients) providing them with test reports (patients receive only negative report directly on their cell phone). See **Figure 2**.

The system is continuously improved due to the increasing participation in large-scale cervical cancer screening activities and therefore database is growing exponentially. For example, parallel to our study in 2018, we performed additional analysis of more than 1.2 million cell samples, adding millions of microscopic images to database. With increasing data, the algorithm is also upgraded and improved, leading to improved diagnosis and detection rates of cervical abnormalities.

In response to the need for timely reporting and analysis of massive data from dispersed areas, Landing has improved its data uploading and downloading efficiencies. Data processing capacity of our "Cyto Cloud" is increased from processing 30 million cell samples per day in the end of 2016 to 750 million per day by the end of 2018.

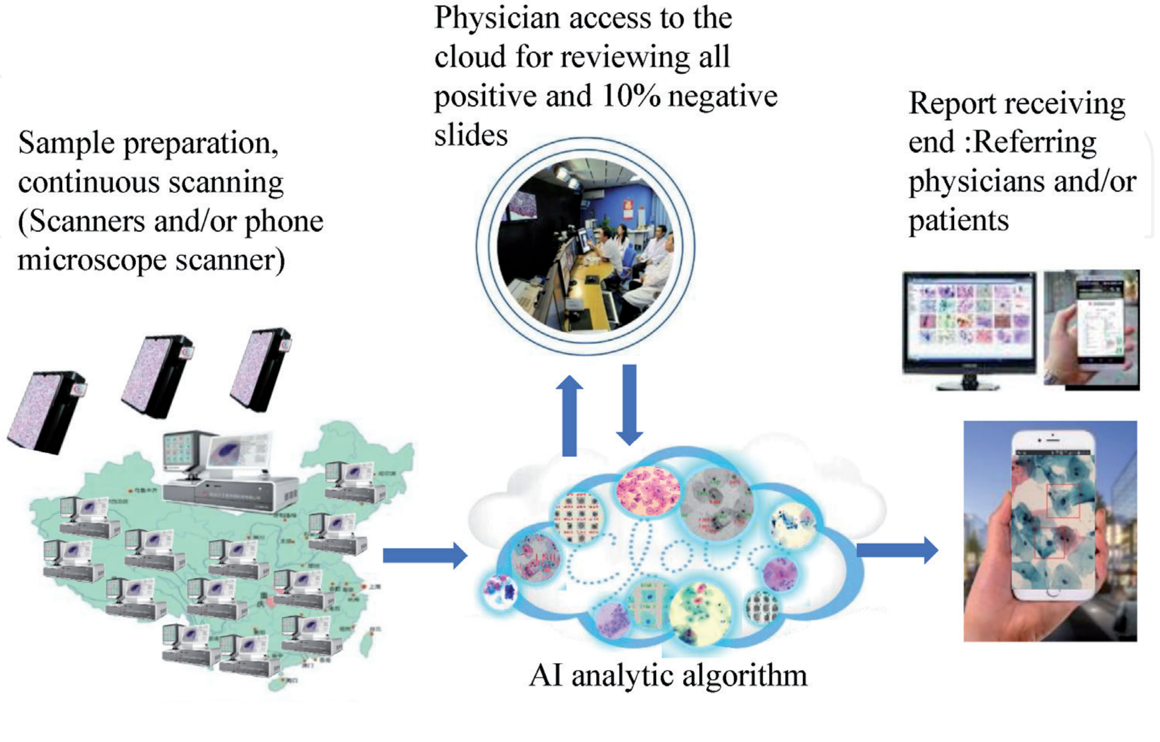

Figure 2.
Operational steps within cervical cancer screening program.

This mode is being proved to be practical in China and can be reproducible in other developing countries wherever cytology is used as only method or is combined with HPV testing. Moreover, technological advancements and data accumulation might enable the AI system to be more intelligent and used more generally in other diagnostic fields.

7. Conclusions

Further development of AI and cloud computing in laboratory medicine is inevitable. Once huge amount of data is collected and analyzed the basic unit of data collection is now ready for a new roll out. In collaboration with a mobile phone companies the next generation of automated scanners is in the form of handheld phone microscopes that can be used in a remote area without lot of infrastructure. (Landing Smart Hand held device) It is important to say that the mobile phone handheld microscope is not only limited for the use in the cervical cancer screening. It is and can be used for any cytology and/or histology slides. While cervical cancers samples are currently the only specimens that use AI for assisted analysis the handheld device can be used for assisted second opinion diagnosis of FNA or bronchial washings or any other type of cytology or histology slides.

AI, fast cloud computing through 5G networks is changing the way we deliver medicine today. These advances are offering tremendous opportunity for improvement of screening programs, particularly in China where huge number of women need to be screened. At the same time our model can be easily applicable, adaptable and implemented anywhere in the world where there is a lack of laboratory professionals and there is a need for a cervical cancer screening improvement.

Conflict of interest

The authors declare no conflict of interest.

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