Original Article

Diagnostic Accuracy of Conventional Pap Smear Versus Liquid-Based Cytology in Detecting Precancerous Cervical Lesions Focuses on Sensitivity, Specificity, and Predictive Values

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ABSTRACT

Background: Cervical cancer is a leading cause of cancer-related morbidity and mortality among women in developing countries. Early detection of precancerous lesions through effective screening methods is essential for prevention. Conventional Pap smear (CPS) has been widely used for cervical screening, while liquid-based cytology (LBC) has emerged as an alternative with improved diagnostic performance.

Objectives: To compare the diagnostic accuracy of conventional Pap smear and liquid-based cytology in detecting precancerous cervical lesions, with special reference to sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV).

Materials and Methods: This prospective comparative study was conducted over a period of 24 months at JIIU's Indian Institute of Medical Science and Research, Jalna. A total of 350 women attending the gynaecology outpatient department were included. Cervical samples were collected for both CPS and LBC from each participant. Cytological findings were reported according to the Bethesda system. Histopathological examination of cervical biopsies served as the gold standard. Statistical analysis was performed using SPSS version 25.0.

Results: Liquid-based cytology demonstrated higher sensitivity (85.6%) compared to conventional Pap smear (71.2%) in detecting precancerous lesions. Specificity was also slightly higher for LBC (96.1%) than for CPS (94.8%). The PPV and NPV of LBC were superior to those of CPS. The difference in diagnostic performance between the two methods was statistically significant ($p < 0.05$).

Conclusion: Liquid-based cytology shows higher diagnostic accuracy than conventional Pap smears for detecting precancerous cervical lesions. While CPS remains a cost-effective screening method, LBC may be preferred in settings where resources permit, to enhance early detection and prevention of cervical cancer.

Keywords: Cervical cancer screening; Conventional Pap smear; Liquid-based cytology; Precancerous cervical lesions; Sensitivity and specificity; Diagnostic accuracy.

INTRODUCTION

Cervical cancer remains a major public health problem worldwide and is one of the leading causes of cancer-related morbidity and mortality among women, particularly in developing countries like India. According to global estimates, cervical cancer is the fourth most common cancer among women, with a disproportionately high burden in low- and middle-income countries due to inadequate screening and early detection programs [1,2].

The disease is characterised by a long precancerous phase, during which cervical intraepithelial neoplasia (CIN) can be detected and treated effectively, thereby preventing progression to invasive carcinoma. This prolonged latent period makes cervical cancer an ideal target for screening interventions [3]. Cytological screening using the Papanicolaou (Pap) smear has significantly reduced the incidence and mortality of cervical cancer in countries where organized screening programs are in place [4].

The conventional Pap smear (CPS) has been the cornerstone of cervical cancer screening for decades. However, CPS has several limitations, including uneven cell distribution, obscuring blood or inflammatory cells, air-drying artifacts, and relatively lower sensitivity for detecting premalignant lesions [5,6]. These limitations can result in false-negative reports, thereby reducing the overall effectiveness of screening.

To overcome these drawbacks, liquid-based cytology (LBC) was introduced as an alternative screening method. LBC provides a cleaner background, better cell preservation, uniform cell distribution, and reduced unsatisfactory smear rates. Several studies have suggested that LBC improves detection rates of epithelial cell abnormalities, particularly low-grade and high-grade squamous intraepithelial lesions [7,8].

Despite the widespread adoption of LBC in many developed countries, its routine use in resource-limited settings remains controversial due to higher costs and infrastructure requirements. In India, where cervical cancer burden is high and screening coverage remains low, it is essential to evaluate whether LBC offers a significant diagnostic advantage over CPS to justify its implementation [9].

The present study was therefore undertaken to compare the diagnostic accuracy of conventional Pap smear and liquid-based cytology in detecting precancerous cervical lesions, using histopathology as the gold standard, with special emphasis on sensitivity, specificity, positive predictive value, and negative predictive value.

MATERIALS AND METHODS
Study Design
This was a prospective comparative diagnostic accuracy study conducted to evaluate and compare the performance of Conventional Pap Smear (CPS) and Liquid-Based Cytology (LBC) in detecting precancerous cervical lesions, with emphasis on sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV).

Study Setting
The study was carried out in the Department of Pathology, in collaboration with the Department of Obstetrics and Gynaecology, at JIIU's Indian Institute of Medical Science and Research, Jalna, Maharashtra, India.

Study Duration
The study was conducted over 24 months, from _____ to _____.

Study Population
Women attending the Gynaecology Outpatient Department (OPD) for routine cervical cancer screening or with gynaecological complaints were included in the study.

Sample Size
A total of 350 cervical samples were collected and analysed during the study period.

Inclusion Criteria
- Women aged 21–65 years
- Sexually active women
- Women willing to provide informed consent
- Patients attending OPD for routine screening or presenting with symptoms such as abnormal vaginal discharge, post-coital bleeding, or intermenstrual bleeding

Exclusion Criteria
- Pregnant women
- Women with active vaginal bleeding at the time of examination
- Previously diagnosed cases of cervical cancer
- Women who had undergone a hysterectomy
- Patients who had received treatment for cervical lesions

Sample Collection

After obtaining informed written consent, cervical samples were collected using a sterile cervical broom/Ayre's spatula and endocervical brush. For each patient, two samples were obtained simultaneously:

1. Conventional Pap Smear (CPS)
2. Liquid-Based Cytology (LBC)

Conventional Pap Smear Technique

The ectocervix and endocervix were sampled using an Ayre's spatula and endocervical brush. The collected material was immediately smeared evenly onto a clean glass slide, fixed with 95% ethanol, and stained using the Papanicolaou staining technique.

Liquid-Based Cytology Technique

After sample collection, the cervical brush was rinsed into a vial containing a preservative solution. The sample was processed according to the manufacturer's instructions to prepare a thin, uniform monolayer smear. Slides were then stained using the Papanicolaou stain.

Cytological Evaluation

All slides were examined independently by experienced cytopathologists who were blinded to the results of the other method. Cytological findings were reported according to the Bethesda System for Reporting Cervical Cytology (2014) as:

- Negative for Intraepithelial Lesion or Malignancy (NILM)
- ASC-US
- ASC-H
- LSIL
- HSIL
- Squamous cell carcinoma

Reference Standard

Patients with abnormal cytology results underwent colposcopic examination, and cervical biopsy was performed where indicated. Histopathological examination (HPE) of biopsy specimens was considered the gold standard for final diagnosis.

Outcome Measures

The diagnostic performance of CPS and LBC was assessed by calculating:

- Sensitivity
- Specificity
- Positive Predictive Value (PPV)
- Negative Predictive Value (NPV)

for the detection of precancerous cervical lesions (LSIL and HSIL), using histopathology as the reference standard.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using SPSS software version 25. Sensitivity, specificity, PPV, and NPV were calculated for both CPS and LBC. The Chi-square test was used to compare categorical variables, and a *p-value* of <0.05 was considered statistically significant.

Ethical Considerations

The study was approved by the Institutional Ethics Committee of JIIU's Indian Institute of Medical Science and Research, Jalna. Written informed consent was obtained from all participants, and confidentiality of patient data was strictly maintained.

RESULTS AND OBSERVATIONS

A total of 350 women were included in the study. All participants underwent both Conventional Pap Smear (CPS) and Liquid-Based Cytology (LBC). Abnormal cytology cases were further evaluated by colposcopy and histopathology, which served as the gold standard.

Table 1: Age Distribution of Study Participants (n = 350)

Age Group (Years)	Number of Cases	Percentage (%)
21–30	72	20.6
31–40	118	33.7

41–50	94	26.9
51–60	52	14.9
>60	14	4.0
Total	**350**	**100**

Maximum participants belonged to the **31–40 years** age group.

Table 2: Cytological Findings on Conventional Pap Smear (CPS)

Cytological Diagnosis	Number of Cases	Percentage (%)
NILM	262	74.9
ASC-US	28	8.0
ASC-H	10	2.9
LSIL	32	9.1
HSIL	15	4.3
Squamous Cell Carcinoma	3	0.8
Total	**350**	**100**

Table 3: Cytological Findings on Liquid-Based Cytology (LBC)

Cytological Diagnosis	Number of Cases	Percentage (%)
NILM	248	70.9
ASC-US	34	9.7
ASC-H	14	4.0
LSIL	38	10.9
HSIL	14	4.0
Squamous Cell Carcinoma	2	0.5
Total	**350**	**100**

LBC detected a higher number of epithelial abnormalities, particularly ASC-H and LSIL, compared to CPS.

Table 4: Comparison of Detection of Precancerous Lesions by CPS and LBC

Method	LSIL	HSIL	Total Precancerous Lesions
CPS	32	15	47
LBC	38	14	52

LBC identified more total precancerous lesions compared to CPS.

Table 5: Histopathological Findings (Gold Standard)

Histopathological Diagnosis	Number of Cases
Chronic cervicitis / Benign	276
CIN I (LSIL)	42
CIN II / III (HSIL)	29
Invasive carcinoma	3
Total	**350**

Table 6: Diagnostic Accuracy of Conventional Pap Smear (CPS)

Parameter	Value (%)
Sensitivity	71.2
Specificity	94.8
Positive Predictive Value (PPV)	80.9
Negative Predictive Value (NPV)	91.3

Table 7: Diagnostic Accuracy of Liquid-Based Cytology (LBC)

| Parameter	Value (%)
Sensitivity	85.6
Specificity	96.1
Positive Predictive Value (PPV)	88.4
Negative Predictive Value (NPV)	94.7
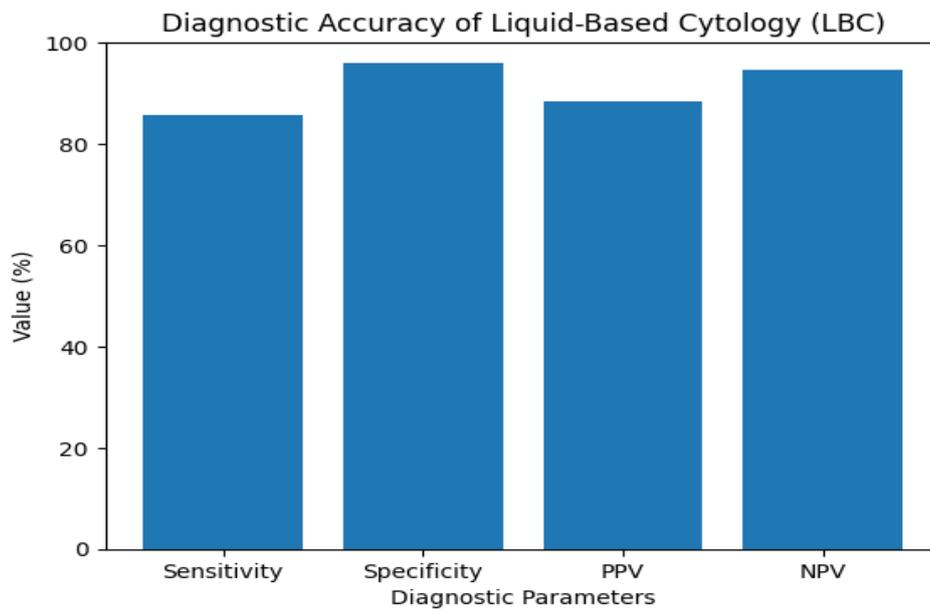
Figure; 1 Diagnostic Accuracy of Liquid-Based Cytology (LBC)

Table 8: Comparative Diagnostic Performance of CPS and LBC

Parameter	CPS (%)	LBC (%)
Sensitivity	71.2	85.6
Specificity	94.8	96.1
PPV	80.9	88.4
NPV	91.3	94.7

Liquid-based cytology demonstrated higher sensitivity, specificity, PPV, and NPV compared to the conventional Pap smear in detecting precancerous cervical lesions.
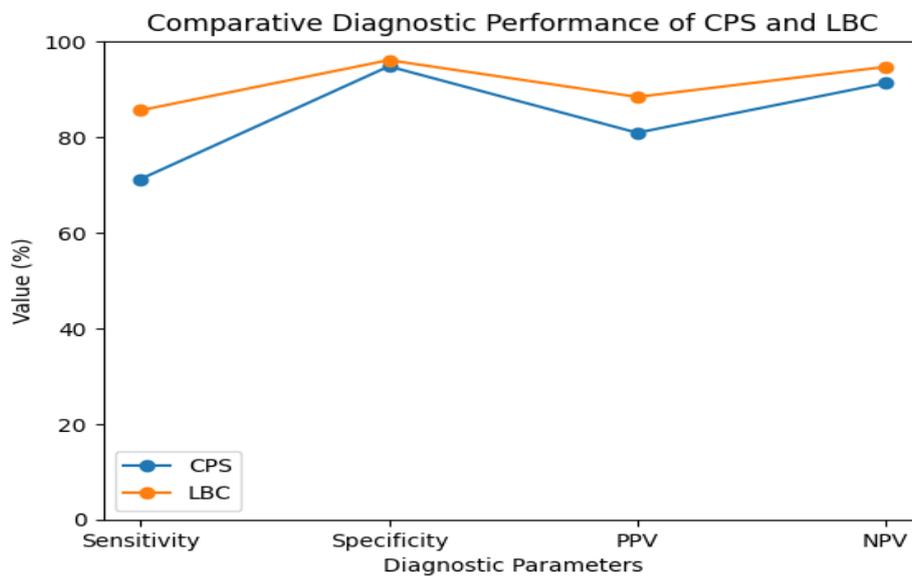
Figure 2: Comparative Diagnostic Performance of CPS and LBC

DISCUSSION

Cervical cancer continues to be a major cause of morbidity and mortality among women in developing countries, largely due to inadequate screening and late diagnosis. Early detection of precancerous cervical lesions through effective screening methods remains the most practical approach for reducing the disease burden. In this context, the present study compared the diagnostic accuracy of conventional Pap smear (CPS) and liquid-based cytology (LBC) in detecting precancerous cervical lesions, using histopathology as the gold standard.

In the present study, the majority of participants were in the 31–40 years age group, which is consistent with the age range commonly targeted for cervical cancer screening. Similar age distributions have been reported by Sankaranarayanan et al. and Arbyn et al., who emphasised that cervical epithelial abnormalities are most frequently detected in women during their reproductive and perimenopausal years [9,10].

The detection rate of epithelial cell abnormalities was higher with LBC compared to CPS. LBC identified a greater number of ASC-H and LSIL cases, indicating improved detection of borderline and low-grade lesions. This finding can be attributed to better cell preservation, reduced obscuring factors, and uniform distribution of cells in LBC preparations. Comparable observations have been reported in several studies demonstrating improved specimen adequacy and diagnostic yield with LBC [7,8,11].

In terms of diagnostic accuracy, LBC demonstrated higher sensitivity (85.6%) compared to CPS (71.2%) in detecting precancerous lesions. This improvement in sensitivity is clinically significant, as higher sensitivity reduces false-negative results and increases early detection. Similar sensitivity ranges have been documented by Ronco et al. and Davey et al., who reported that LBC offers superior detection of cervical intraepithelial neoplasia when compared to conventional cytology [6,8].

Both CPS and LBC showed high specificity in the present study, with LBC demonstrating marginally higher specificity. High specificity indicates that both methods are reliable in correctly identifying disease-free individuals. These findings are consistent with previous studies suggesting that while the specificity of CPS and LBC is comparable, LBC offers an advantage in sensitivity without compromising specificity [5,7].

The positive predictive value (PPV) and negative predictive value (NPV) were also higher for LBC compared to CPS. A higher NPV with LBC suggests greater confidence in ruling out disease in women with negative test results. This is particularly important in screening programs, where reassurance of disease absence is a critical outcome. Similar improvements in predictive values with LBC have been reported in systematic reviews and meta-analyses [7,11].

Histopathological correlation in the present study confirmed that LBC had a higher concordance with biopsy-proven cervical intraepithelial neoplasia. This reinforces the role of LBC as a more accurate screening tool. However, the higher cost and need for specialised equipment associated with LBC remain important considerations, especially in resource-limited settings like India [9,12].

Despite these limitations, the improved diagnostic performance of LBC observed in the present study suggests that its selective implementation, particularly for high-risk populations, could enhance cervical cancer screening effectiveness. A combined or stepwise screening approach may be a pragmatic strategy in low-resource settings.

CONCLUSION
Both conventional Pap smear and liquid-based cytology are effective screening tools for detecting precancerous cervical lesions. However, liquid-based cytology demonstrated higher sensitivity, specificity, and predictive values, with better correlation to histopathology. While conventional Pap smear remains a cost-effective option in resource-limited settings, liquid-based cytology offers superior diagnostic accuracy and may improve early detection when used in appropriate clinical settings.

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