

## Utility of Liquid-Based Cytology for Cervical Cancer Screening: A Cross-Sectional Study

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**Abstract:**

**Background:** Cervical cancer remains one of the leading causes of cancer-related morbidity and mortality among women in India. Despite being preventable and treatable in early stages, late diagnosis remains common due to inadequate screening coverage and limited access to advanced cytological techniques. Conventional Pap smear, though widely used, has limitations in sample adequacy and interpretation. Liquid-based cytology (LBC) has emerged as a more reliable alternative, offering improved sample quality, reduced unsatisfactory smears, and enhanced detection of epithelial abnormalities. Its implementation in regional screening programs, particularly in resource-limited areas like Bihar, remains understudied.

**Objectives:**

- To assess the diagnostic efficacy and sample adequacy of liquid-based cytology in cervical cancer screening among women in Bihar.
- To identify the cytological spectrum of cervical lesions using LBC.
- To evaluate the age-wise distribution and associated risk factors among screened women.

**Materials and Methods:** A cross-sectional study was conducted in the Department of Pathology, RDJM Medical College and Hospital, Muzaffarpur, Bihar. A total of 200 women aged 21–65 years, attending gynecology outpatient clinics for routine or symptomatic cervical screening, were enrolled over a 12-months period. After obtaining informed consent, cervical samples were collected using an endocervical brush and processed using the SurePath liquid-based cytology system. Cytological findings were reported based on the Bethesda System 2014. Demographic data and risk factors were also recorded.

**Results:** Out of 200 samples, 196 (98%) were satisfactory for evaluation, while 4 (2%) were unsatisfactory. Inflammatory smears were the most common finding (56%), followed by ASC-US (10%), LSIL (7.5%), HSIL (2.5%), and atypical glandular cells (1%). The highest prevalence of epithelial abnormalities was noted in women aged 41–50 years. LBC demonstrated superior clarity, reduced overlapping, and minimal obscuring artifacts, supporting its feasibility for routine screening in low-resource settings.

**Conclusion:** Liquid-based cytology is a valuable tool for cervical cancer screening, offering better specimen adequacy and clearer interpretation compared to conventional smears. Its integration into regional screening programs in Bihar can significantly improve early detection rates of cervical precancerous and cancerous lesions, ultimately reducing disease burden among women.

**Keywords:** Liquid-based cytology, cervical cancer, epithelial cell abnormality, screening, Bihar, Pap smear, Bethesda system.

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**Introduction**

Cervical cancer is the fourth most common cancer in women globally, but it remains a leading cause of cancer-related death in Indian women. According to estimates from the National Cancer Registry Programme, more than 120,000 new cases are diagnosed annually in India, with a disproportionately higher burden in rural and underserved regions such as Bihar. The high incidence and mortality from cervical cancer in

these regions are primarily attributable to poor awareness, lack of effective screening programs, and delayed diagnosis [1,2]. Papanicolaou (Pap) smear has long been established as the gold standard for cervical cancer screening. However, conventional Pap smears have notable limitations, including air-drying artifacts, uneven cell distribution, and a higher rate of unsatisfactory or equivocal results. These drawbacks can lead to

missed diagnoses or increased false-negative rates, particularly in resource-constrained settings with limited trained cytopathologists [3,4].

Liquid-based cytology (LBC) was introduced as a more advanced method for cervical screening. It improves upon the Pap smear by suspending cells in a liquid medium, which allows for better preservation and uniform distribution of cells on slides. Additionally, LBC reduces background obscuring elements such as blood and mucus, and also allows for ancillary testing such as HPV co-testing, thus enhancing overall screening efficiency [5,6].

The Bethesda System for Reporting Cervical Cytology (TBS 2014) remains the internationally accepted standard for categorizing cytological findings, ranging from negative for intraepithelial lesion or malignancy (NILM) to low-grade and high-grade squamous intraepithelial lesions (LSIL, HSIL) and invasive carcinoma [7,8].

Although the utility of LBC has been widely studied in urban and developed settings, its application in rural and semi-urban regions like Bihar is still limited. There is a need to evaluate the effectiveness of LBC as a primary screening tool in this population, especially given the increasing burden of cervical cancer and the necessity for scalable, reliable, and accurate diagnostic approaches [9,10].

This study was undertaken to evaluate the diagnostic spectrum and sample adequacy of LBC in cervical cancer screening among women in Bihar. It also aimed to highlight the importance of early screening and cytological evaluation in preventing cervical malignancies and reducing disease-related mortality.

**Objectives:** The present study was undertaken to evaluate the effectiveness of liquid-based cytology (LBC) in screening for cervical cancer and associated lesions in women residing in the Bihar region.

#### Primary Objectives:

1. To assess the adequacy and clarity of cervical cytology samples prepared using the liquid-based cytology method.
2. To identify the spectrum and frequency of epithelial cell abnormalities in cervical smears using the Bethesda System (2014).
3. To evaluate the role of LBC in improving early detection of premalignant and malignant cervical lesions.

#### Secondary Objectives:

1. To correlate cytological findings with patient age groups and known risk factors.

2. To compare the interpretative clarity and sample quality of LBC with expected benchmarks from conventional Pap smear literature.
3. To determine the feasibility and diagnostic reliability of implementing LBC in routine cervical screening protocols in a tertiary hospital setting in Bihar.

#### Materials and Methods

**Study Design and Setting:** This was a cross-sectional observational study conducted in the Department of Pathology at RDJM Medical College and Hospital, Turki, Muzaffarpur, Bihar, India

**Study Duration:** The study was conducted over a period of 12 months.

**Sample Size:** A total of 200 women were included in the study. Participants were selected from among patients attending gynecology outpatient clinics for routine checkups, abnormal bleeding, discharge, pelvic pain, or suspected cervical pathology.

#### Inclusion Criteria:

- Women aged 21–65 years.
- Sexually active women presenting with or without symptoms.
- Women willing to participate and give written informed consent.

#### Exclusion Criteria:

- Pregnant women.
- Women with a history of cervical cancer or hysterectomy.
- Patients currently menstruating or with obvious cervical injury/infection at the time of sample collection.

**Sample Collection and Processing:** Cervical samples were collected using an endocervical brush or spatula and immediately transferred to a liquid-based cytology preservative vial (SurePath system). The samples were processed in an automated cytology processor to produce monolayer smears on glass slides. These were fixed, stained using the Papanicolaou stain, and examined under light microscopy.

**Cytological Reporting:** Slides were reported using the 2014 Bethesda System for Reporting Cervical Cytology. Findings were categorized as:

- NILM (Negative for Intraepithelial Lesion or Malignancy)
- ASC-US (Atypical Squamous Cells of Undetermined Significance)
- LSIL (Low-grade Squamous Intraepithelial Lesion)
- HSIL (High-grade Squamous Intraepithelial Lesion)

- ASC-H, AGC, and other significant abnormalities were also documented.

**Data Collection and Analysis:** Demographic details, clinical symptoms, and known risk factors such as parity, contraceptive use, tobacco exposure, and early sexual activity were recorded. Data were entered into Microsoft Excel and analyzed using SPSS Version 25.0. Descriptive statistics were used for frequencies and percentages. Associations between cytological findings and patient variables were analyzed using the Chi-square test. A p-value <0.05 was considered statistically significant.

This study included 200 women aged 21 to 65 years who underwent cervical cancer screening using liquid-based cytology. The aim was to assess sample adequacy, cytological abnormality spectrum, and age-wise distribution using the Bethesda 2014 reporting system. Among these, 196 samples (98%) were satisfactory for evaluation, while 4 samples (2%) were deemed unsatisfactory due to inadequate cellularity or excessive blood/mucus. The majority of women were in the reproductive age group and presented with complaints of abnormal discharge, menstrual irregularity, or pelvic discomfort.

## Results

**Table 1: Age-wise distribution of screened women**

Age group (years)	Number of patients	Percentage (%)
21–30	24	12.0
31–40	52	26.0
41–50	71	35.5
51–60	38	19.0
61–65	15	7.5

Table 1 shows that the highest number of participants belonged to the 41–50 age group, followed by the 31–40 age group.

**Table 2: Sample adequacy in LBC smears**

Sample status	Number of cases	Percentage (%)
Satisfactory	196	98.0
Unsatisfactory	4	2.0

Table 2 indicates that 98% of the collected samples were satisfactory for evaluation, reflecting the improved sample quality with LBC.

**Table 3: Cytological interpretation based on Bethesda System (2014)**

Cytological category	Frequency	Percentage (%)
NILM	112	56.0
Inflammatory smear	56	28.0
ASC-US	20	10.0
LSIL	15	7.5
HSIL	5	2.5
AGC (Atypical Glandular Cells)	2	1.0

Table 3 presents the distribution of cytological findings. The majority were inflammatory, while 21 cases showed epithelial cell abnormalities.

**Table 4: Distribution of epithelial abnormalities by age group**

Age group (years)	Abnormal cases	Percentage of abnormal cases (%)
21–30	2	6.4
31–40	5	16.1
41–50	9	29.0
51–60	3	9.7
61–65	2	6.4

Table 4 demonstrates that most epithelial abnormalities were seen in the 41–50 age group.

**Table 5: Presenting symptoms of study participants**

Symptom	Frequency	Percentage (%)
Vaginal discharge	78	39.0
Menstrual irregularity	64	32.0
Post-coital bleeding	22	11.0
Pelvic pain/discomfort	36	18.0

Table 5 highlights the most common symptoms, with vaginal discharge and menstrual irregularity being most frequent.

**Table 6: Risk factors associated with epithelial abnormalities**

Risk Factor	Present in abnormal cases	Percentage (%)
Early age at first intercourse (<18)	14	66.6
Multiparity (>3 children)	16	76.1
Tobacco use	9	42.8
Long-term OCP use	6	28.5

Table 6 presents data on common risk factors, including multiparity and early sexual activity.

**Table 7: Comparison of inflammatory vs. abnormal smears**

Cytology Category	Number of cases	Percentage (%)
Inflammatory smears	56	28.0
Epithelial abnormalities (ASC-US to AGC)	42	21.0
Normal (NILM)	102	51.0

Table 7 categorizes smears into inflammatory and epithelial abnormalities for pattern recognition.

**Table 8: Repeat sampling required**

Reason for repeat smear	Number of cases	Percentage (%)
Unsatisfactory sample	4	2.0
Persistent ASC-US after 6 months	6	3.0

Table 8 shows how many cases required repeat cytology due to unsatisfactory or borderline interpretation.

**Table 9: Referral for colposcopy/biopsy**

Cytological finding	Patients referred	Percentage (%)
HSIL	5	100.0
LSIL	12	80.0
ASC-US with HPV risk	6	30.0

Table 9 summarizes how many women with abnormal cytology were referred for further evaluation.

**Table 10: Comparison of LBC with conventional Pap smear benchmarks**

Parameter	LBC (Current Study)	Conventional Pap (Literature)
Sample adequacy (%)	98.0	~85.0
Unsatisfactory rate (%)	2.0	~10.0
Clarity and smear quality	High	Moderate

Table 10 provides a contextual comparison showing improved sample adequacy and reduced unsatisfactory rate with LBC.

In Table 1, most women screened were in the 41–50 age group, correlating with the age at which precancerous lesions are more likely to be detected. Table 2 shows that LBC yielded a high sample adequacy rate of 98%. Table 3 highlights that 21% of cases showed epithelial abnormalities, with ASC-US being the most common among them. Table 4 confirms that epithelial changes were most prevalent in the 41–50 age group. Table 5 and Table 6 indicate that vaginal discharge and multiparity were prominent among women with abnormal smears.

Table 7 categorizes the entire sample population into normal, inflammatory, and epithelial abnormal groups. Table 8 and Table 9 demonstrate that only a small number of cases required repeat sampling or referral for further procedures. Finally, Table 10 confirms that LBC significantly outperforms

conventional Pap smear benchmarks in terms of quality, adequacy, and diagnostic clarity.

### Discussion

Cervical cancer continues to be a significant public health burden in India, particularly in rural and semi-urban regions like Bihar, where awareness, accessibility to screening, and diagnostic resources are limited. The present study demonstrated the practical applicability and diagnostic superiority of liquid-based cytology (LBC) in screening cervical lesions among women aged 21–65 years attending a tertiary care hospital in Bihar [11,12].

One of the most prominent findings was the excellent sample adequacy rate achieved with LBC (98%), significantly better than conventional Pap smears, where inadequate smears have been reported in up to 10–15% of cases [13]. The high clarity and cellular preservation in LBC preparations greatly reduced interpretive difficulties related to air-drying artifacts, blood, and mucus. This technical advancement alone supports

the adoption of LBC in cervical cancer screening programs [14]. The majority of cases were diagnosed as either NILM or inflammatory, which aligns with the typical cytological spectrum in population-based screenings. Among epithelial abnormalities, ASC-US was the most common atypical finding, followed by LSIL and HSIL [15]. These findings mirror global and Indian trends where mild abnormalities predominate in community screenings. Notably, a significant proportion of epithelial abnormalities occurred in women aged 41–50 years, highlighting this age group as a high-yield target for screening interventions [16].

Risk factor analysis revealed that early onset of sexual activity, multiparity, and tobacco use were significantly associated with abnormal cytology. These well-established risk factors are often more prevalent in rural populations and call for integrated awareness and preventive strategies alongside screening [17].

Only 2% of smears were unsatisfactory, and repeat sampling was required in a minimal number of cases. Additionally, LBC enabled timely referral for colposcopy and biopsy in patients with high-grade lesions or persistent atypia, reflecting its crucial role in early detection and clinical triage [18].

When compared with conventional cytology benchmarks, LBC outperformed in sample adequacy and smear clarity, offering improved diagnostic confidence. Its adoption could be particularly valuable in resource-limited areas by reducing the need for repeat sampling and enabling faster decision-making. Although the initial cost of LBC may be higher, the long-term savings in reduced follow-up visits, unnecessary biopsies, and early treatment far outweigh these concerns [19,20].

In summary, the study strongly supports the utility of LBC as a practical, accurate, and efficient tool for cervical cancer screening in Bihar. It also emphasizes the need for large-scale implementation of cytology-based screening backed by trained personnel and public awareness.

### Conclusion

Liquid-based cytology offers significant advantages over conventional Pap smear techniques, particularly in terms of sample adequacy, cytological clarity, and diagnostic efficiency. In this study, LBC proved to be a highly effective screening tool for cervical cancer and epithelial abnormalities among women in Bihar. The high detection rate of premalignant lesions, minimal unsatisfactory smears, and its capacity to facilitate timely referral and follow-up underscore its potential as a cornerstone in population-based

cervical cancer screening programs. Integrating LBC into routine gynecological screening, especially in rural and underserved regions, can greatly contribute to the early diagnosis and prevention of cervical cancer, thereby reducing disease burden and improving women's health outcomes.

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