Section: Pathology

Original Research Article

HUMAN VERSUS MACHINE: COMPARATIVE EFFECTIVENESS OF FLUID MODE IN BODY FLUID ANALYSIS

Paurash Bansal[1], Alok Mohan[2], Jyotishna Shukla[3], Anupam Varshney[4]

[1]PGJR3, Department of Pathology, Muzzafarnagar Medical College Begrajpur, Muzzafarnagar, India.
[2]Professor, Department of Pathology, Muzzafarnagar Medical College Begrajpur, Muzzafarnagar, India.
[3]Assistant Professor, Muzzafarnagar Medical College Begrajpur, Muzzafarnagar, India.
[4]Professor & Head, Department of Pathology, Muzzafarnagar Medical College Begrajpur, Muzzafarnagar, India.

Received *: 14/04/2026*
Received in revised form *: 04/06/2026*
Accepted *: 19/06/2026*

Corresponding Author:
Dr. Alok Mohan,
Professor, Department of Pathology, Muzzafarnagar Medical College Begrajpur, Muzzafarnagar, India.
Email: dr.alokmohansinha@gmail.com

DOI: 10.70034/ijmedph.2026.3.89

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (3); 545-549

ABSTRACT

Background: Body fluid analysis plays a pivotal role in the diagnosis and management of infectious, inflammatory, and malignant conditions, although manual hemocytometric evaluation remains the conventional gold standard, it is labor intensive and subject to inter-observer variability. Automated hematology analyzers with dedicated body fluid (BF) modes offer potential advantages in precision and turnaround time. The aim is to compare the Body Fluid mode of Mindray automated hematology analyzer with the manual counting method for cytological evaluation of body fluids. Settings and Design: Hospital Based Observational Study.

Materials and Methods: This hospital-based observational study was conducted over 18 months in the Department of Pathology, of a tertiary teaching hospital. A total of 2530 body fluid samples were analyzed. Total nucleated cell counts and differential cell counts were performed manually using an Improved Neubauer chamber and cytological staining and compared with automated analysis using the Mindray BC-760 in Body Fluid ―BF mode. Statistical analysis used: Chi Square test, Spearman rho correlation, Passing Bablok Regression.

Results: Pleural fluid constituted the majority of samples (n= 1300; 51.38%), followed by ascitic fluid (n=950; 37.55%). Mean age was 44.8 ± 19.2 years, with near-equal gender distribution. Automated and manual methods showed comparable median (IQR) TNCC and differential leucocyte counts across most fluid types, with statistically significant correlations.

Conclusion: Automated body fluid analysis demonstrates strong agreement with manual counting for quantitative parameters and enhances laboratory efficiency. Yet, a combined approach ensures optimal diagnostic accuracy in body fluid cytology.

Keywords: Automated, Body Fluid, Hematology, Manual Microscopy, TNCC.

INTRODUCTION

Mesothelial cells form a protective monolayer that lines the serous body cavities.[1] Cerebrospinal fluid system (CSF) is synthesized by the choroid plexus epithelium and ependymal cells of the ventricles and has unique cellular environment.[2,3]

Effusion denotes the abnormal collection of fluid within a serous cavity during pathological processes.[4]

Recently, specialized "Body Fluid" mode has been developed for automated evaluation of body fluid specimens. Automation offers improvement in analytical precision, accuracy, cost-effectiveness, and laboratory efficiency.[5]

The present study was aimed to compare manual and automated methods of body fluid analysis for their diagnostic efficiency and practical applicability.

MATERIALS AND METHODS

The present study was a hospital-based observational study, conducted in the department of Pathology, in a tertiary teaching hospital in Western Uttar Pradesh, India after getting proper approval from Institutional Ethical Committee [MMC/IEC/2024/372] and strictly following inclusion and exclusion criteria, 2530 patients of body fluids were included in the study.

Sample size: A total of 2530 samples were studied. (Duration period for data collection according to inclusion criteria and last three years' average.) Sampling technique was convenience sampling technique.

Inclusion criteria

1. Body fluids received in the Department of Pathology.
2. Patients willing to participate.
3. Cerebrospinal fluid with quantity more than or equal to 2 ml.
4. Serous body fluids (pleural, peritoneal and pericardial fluid) with quantity more than or equal to 50 ml.

Exclusion Criteria

1. Fluids sent without proper clinical details or in improper vials.
2. Fluids with less than specified quantity of volume.
3. Frankly hemorrhagic body fluids. 4. Synovial fluids.

Fluids were collected in a sterile wide-mouth universal container with proper labelling and identification number. Processing was done immediately after receiving. If there was any delay in transport it was refrigerated at 4 degrees Celsius. Essential clinical details were recorded. Physical examination (volume, color, appearance and coagulum) and microscopic examination of fluid in the form of TNCC and Differential Counts were done. For TNCC fluid was examined manually by modified Neubauer chamber and automated analyzer MINDRAY BC 760. For Differential Counts, after centrifugation for (1500 rpm for 5 min/ cytospin) slides were stained with May Grunwald Giemsa (MGG) for dry smears and Hematoxylin and Eosin (H&E) and Papanicolaou (Pap) for wet smears. Smears were examined and cytological findings were noted. The statistical methods were applied for statistical analysis. To assess the agreement between manual and automated cell counts Passing–Bablok regression analysis was done. P-value of < 0.05 were considered as significant at C.I. of 95%.

RESULTS

A total of 2530 body fluids samples were evaluated. Comparative analysis of body fluids was done between automated and manual methods. The highest number of cases occurred in the 51–60 year and 41–50-year age groups, suggesting a higher prevalence of fluid-related complications in middle-aged and elderly populations. The mean age of the patients was 44.80 ± 19.20 years.

Out of the total 2530 individuals, there were 1280 females (51%) and 1250 males (49%). Females (n= 1280; 51%) were slightly more as compared to males (n= 1250; 49%) in present study. Male is to female ratio came out to be 1:1.024.

Pleural Fluid was the most frequently analyzed fluid, accounting for over half of all cases.

The [Table 2] demonstrates strong agreement between manual and automated methods for analyzing body fluids. Total nucleated cell counts are comparable, with automated values slightly higher but clinically consistent. Neutrophil percentages are low in CSF, moderate in pleural and ascitic fluids, and markedly elevated in pericardial fluid, indicating acute inflammation. Mononuclear cells predominate in CSF and serous fluids, while reduced in pericardial samples. Automated analysis shows a mild increase in neutrophils and corresponding decrease in mononuclear cells. All parameters show statistically significant variation across fluid types ($p < 0.001$).

Automated counts were significantly higher than manual counts for total nucleated cell count (Auto: 473 [157–1904] vs. Manual: 420 [160–1700], $p < 0.001$). For neutrophils percentage (11 [4.3–34.5] vs. 9 [5–30], $p = 0.424$) and mononuclear cells percentage (89 [65.5–95.7] vs. 91 [70–95], $p = 0.424$), no significant differences were observed, indicating good agreement between methods for differential counts in [Table 3].

All correlations are positive and statistically significant ($p < 0.001$) shown in [Table 4], indicating that automated cell count measurements reliably agree with manual measurements. The total nucleated cell count shows an almost perfect correlation ($\rho = 0.988$), while neutrophil and mononuclear percentages show strong correlations ($\rho \approx 0.932$).

To assess the agreement between manual and automated total nucleated cell counts, we performed a Passing–Bablok regression analysis. This non-parametric regression method is widely recommended for method comparison studies, as it is robust against outliers and does not assume normal distribution of measurement errors. The analysis provides estimates of the intercept (constant bias) and slope (proportional bias), along with their 95% confidence intervals. (as shown in Figure 1)

a) Assessment of agreement between manual and automated for total cell counts Passing–Bablok regression yielded the equation:

The intercept (–0.50, 95% CI: –3.69 to 2.23) was not significantly different from zero, indicating no constant bias between the two methods. The slope (0.96, 95% CI: 0.93 to 0.995) was significantly less than one, suggesting a small but systematic proportional bias. This means that the automated method tends to underestimate total nucleated cell counts compared with the manual reference method, particularly at higher values.

b) Assessment of agreement between manual and automated for Neutrophil percentage

Intercept (0.00, 95% CI: –0.21 to 0.20): The confidence interval includes 0, which indicates there is no significant constant bias between manual and automated neutrophil percentage measurements. Slope (1.00, 95% CI: 0.99 to 1.02): The confidence interval includes 1, meaning there is no significant proportional bias. The automated method scales almost identically to the manual method across the full range of values. Overall Agreement: - The Passing–Bablok regression suggests that the manual and automated methods are in excellent agreement for neutrophil percentage. Both constant and proportional bias are absent, indicating the automated system can be considered equivalent to the manual reference for this parameter.

c) Assessment of agreement between manual and automated for Mononuclear cell percentage

Intercept (–0.46, 95% CI: –2.11 to 1.03): The confidence interval includes 0, meaning there is no significant constant bias between manual and automated mononuclear percentage measurements. Slope (1.00, 95% CI: 0.99 to 1.02): The confidence interval includes 1, meaning there is no significant proportional bias. The relationship between manual and automated mononuclear percentages is effectively one-to-one. Overall Agreement: Both methods show excellent agreement for mononuclear percentages. There is neither constant nor proportional bias, suggesting the automated method provides results equivalent to the manual reference method for this parameter.

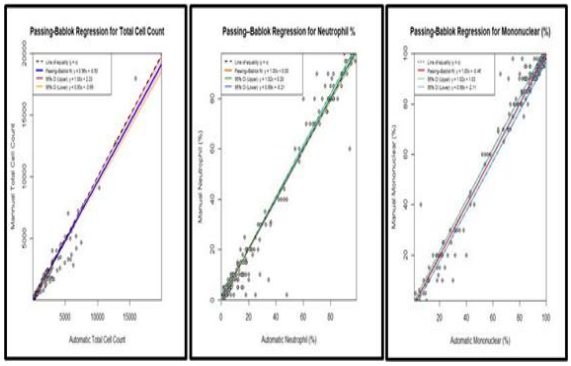

Figure 1: Passing- Bablok Regression for Manual vs Automated Total Nucleated Cell Count; Neutrophil % and Mononuclear cell %

Table 1: Fluid wise distribution of cases

Body Fluid	TOTAL	% age
Non- Serous Body Fluids		
Cerebrospinal Fluid	250	9.88
Serous Body Fluids		
Pleural Fluid	1300	51.38
Ascitic Fluid	950	37.55
Pericardial Fluid	30	1.19
TOTAL	2530	100

Table 2: The descriptive statistics median (IQR) of TNCC, Neutrophil % and Mononuclear cell % stratified by fluid type

Variable		CSF (n=250)	Pleural Fluid (n=1300)	Ascitic Fluid (n=950)	Pericardial Fluid (n=30)	p-value
Total Nucleated Cell Count	Manual	7 (5–20)	1085 (355–2300)	250 (125–890)	200 (110–1100)	<0.001
	Automated	7 (4–23)	1089 (384–2577)	271 (147-965)	211 (132–1245)	<0.001
Neutrophil %	Manual	0 (0–10)	9.5 (5–31)	10 (5–30)	80 (75–85)	<0.001
	Automated	2.2 (0–12.8)	11.2 (4.2–36.2)	12 (5.7–32.4)	77 (76–82)	<0.001
Mononuclear Cell %	Manual	100 (90–100)	90.5 (69–95)	90 (70–95)	20 (15–25)	<0.001
	Automated	97.8 (87.2–100)	88.9 (63.8–95.8)	88 (67.6–94.3)	23 (18–24)	<0.001

Table 3: Comparison of Manual and Automated Total Nucleated Cell Counts and Differentials (Median [IQR])

Parameter	Method	Median (IQR)	p-value
Total Nucleated Cell Count	Manual	420 (160 – 1700)	<0.001 **
	Automated	473 (157 – 1904)	
Neutrophil %	Manual	9 (5 – 30)	0.424
	Automated	11 (4.3 – 34.5)	
Mononuclear Cell%	Manual	91 (70 – 95)	0.424
	Automated	89 (65.5 – 95.7)	

Table 4: Spearman Correlation between Manual and Automated Cell Counts

Variables	Spearman's rho (ρ)	p-value
Total nucleated cell count (Manual vs Automated)	0.9883	<0.001
Neutrophil percentage (Manual vs Automated)	0.9319	
Mononuclear cell percentage (Manual vs Automated)	0.9319	

DISCUSSION

The present study was aimed to compare cytological analysis of body fluids by manual versus automated method with reference to a) Total nucleated cell count b) Differential leucocyte cell counts and clinicopathological correlation of the fluid.

In the present study, the highest number of cases occurred in the 51–60 and 41–50 age groups. The mean age came out to be 44.80±19.20 years). The mean age recorded by the study of Martín MJ et al,[6] (2021) was at 63 years. The lower mean age was recorded in study by Singh J et al,[7] (2024) at 42.2 years followed by Chatterjee P et al,[8] (2023) study at 44 years & Baig MA et al,[9] (2015) study at 46 years.

Present study showed a nearly equal gender distribution with a slight female preponderance. Present results aligned closely with the trends seen in the studies by Kolte S et al,[10] (2022) and Nayak K et al,[11] (2025), where the gap between genders was narrowing and slightly tilted toward females.

In the present study, total cases studied were 2530 comprising maximum of pleural fluids- 1300 cases (51.39%) followed by ascitic fluid- 950 cases (37.55%) followed by CSF samples- 250 cases (9.88%) and pericardial fluid- 30 cases (1.18%).

Baria R et al,[12] (2025) had the highest number of pleural fluid samples (612), constituting 75.1% of their total cases. Peritoneal/ascitic fluid was the most frequently sampled fluid type across studies, with high sample numbers reported in study by Aanif S et al,[13] (230 cases), and Siatkowski et al,[14] (101 cases).

Manual vs automated cell counter comparison with other studies

Comparable results were seen in the study by Cho J et al (2020), who evaluated overall agreement between automated analyzers (UniCel DxH 800, Sysmex XN-350, UF-5000) and manual counting for total nucleated and RBC counts across body fluids. The study reinforced that automated analyzers improve turnaround time but cannot fully replace manual cytological confirmation, especially for atypical/malignant cells.[15]

Savcı U et al (2020) also emphasized on the same findings as present study & found strong concordance between manual hemocytometry and BF mode of Mindray BC-6800 for WBC counts. The study recommended manual counting for low-cellularity samples (<100 cells/mL), supported automation as a screening rather than definitive diagnostic tool.[16]

Similar study done by Martín MJ et al (2021) also provided a comprehensive overview of Sysmex hematology analyzers ("XN-BF mode") and their analytical performance. The study stressed the indispensable role of optical microscopy as the diagnostic gold standard & supported a hybrid workflow integrating automation with manual review.[6]

The results of present study were in concordance with Ivady G et al (2022), who demonstrated strong correlation between Sysmex XN analyzers, flow cytometry, and manual microscopy for non-neoplastic fluids. The study supported automation in uncomplicated samples while recommending microscopy when malignancy is suspected.[17]

Other similar study carried by Saini A et al (2023) demonstrated good diagnostic accuracy of HF-BF parameters on Sysmex XN-1000 using ROC analysis. The study highlighted significantly higher HFC counts in malignant effusions across fluid types & supported automation as an effective malignancy screening adjunct, not a replacement for cytomorphology.[18]

Yoon S et al (2023) in their study evaluated the Sysmex DI-60 and XN-350 digital morphology analyzer, finding high overall sensitivity (83.1–99.4%) for neutrophils, lymphocytes, and macrophages, and strong agreement (k=0.89) between its pre-classification and manual verification. The study showed strong agreement with manual counting and XN-350, particularly for neutrophils and lymphocytes & suggested DI-60 as a viable screening and workload-reducing tool.[19]

Comparable results were seen in the study by Chatterjee P et al (2023), who compared manual hemocytometer counting with an automated hematology analyzer HORIBA H2500 for body fluid analysis in a prospective cross-sectional study (n=311). In the study, automated counts showed good concordance with manual methods for total cell counts, but manual cytology remained essential for morphological interpretation and malignancy detection; reinforcing the role of automated analyzers as adjunct tools, not replacements, in serous fluid cytology.[8]

The results of present study were found in concordance with study by Chaturvedi S et al (2024), who evaluated Automated Sysmex XN-1000 automated body fluid module with manual Improved Neubauer Chamber methods for absolute WBC and RBC counts which showed high correlation and agreement ($r > 0.9$). It was an acceptable alternative for total counts but is not recommended as a replacement for manual differential cytologic workups.[20]

Shin E et al (2024) also emphasized on similar findings as present study & demonstrated high correlation ($r = 0.72–0.94$) between Sysmex DI-60 digital morphology analyzer (post-verification) and manual counts for common leukocyte populations. The study highlighted that digital morphology requires expert verification and currently increases workload in complex effusions.[21]

CONCLUSION

Evaluation of body fluids is a simple, rapid, safe, and cost-effective procedure that assists clinicians in establishing a diagnosis and monitoring disease

progression. Automated body fluid analysis demonstrates high fundamental accuracy and serves as a valuable adjunct for cell count assessment in pleural, ascitic fluids, and cerebrospinal, particularly in emergency settings. This approach offers superior reproducibility, precision, and accuracy, along with rapid and reliable reporting of WBC and RBC counts, and facilitates easier quality control and standardization compared with manual methods.

Fully automated analysis fulfils both time and quality requirements, ensures objectivity in sample handling, and promotes inter-laboratory uniformity; however manual microscopy remains the gold standard.

REFERENCES

1. Mutsaers SE. The mesothelial cell. Int J Biochem Cell Biol. 2004;36(1):9-16. doi: 10.1016/S1357-2725(03)00242-2.
2. Sakka L, Coll G, Chazal J. Anatomy and physiology of cerebrospinal fluid. Eur Ann Otorhinolaryngol Head Neck Dis. 2011;128(6):309-316. doi: 10.1016/j.anorl.2011.03.002.
3. Husain AN, Colby TV, Ordóñez NG, Krausz T, Attanoos R, Beasley MB, et al. Guidelines for pathologic diagnosis of malignant mesothelioma: 2009 update of the consensus statement from the International Mesothelioma Interest Group. Arch Pathol Lab Med. 2009;133(8):1317- 1331. doi: 10.1043/1547-0091-133.8.1317.
4. Shivakumarswamy U, Arakeri SU, Karigowdar MH, Yelikar BR. Diagnostic utility of the cell block method versus the conventional smear study in pleural fluid cytology. J Cytol. 2012;29(1):11-15. doi: 10.4103/0970-9371.93210.
5. Shubhada B, Nayak S, Kumbhalkar D. Evaluation of cell block technique in the cytodiagnosis of body fluids. Int J Sci Res. 2013;4(7):87-94.
6. Alcaide Martín MJ, Altimira Queral L, Sahuquillo Frías L, Valiña Amado L, Merino A, García de Guadiana-Romualdo L. Automated cell count in body fluids: a review. Adv Lab Med. 2021;2(2):149-161. doi: 10.1515/almed-2021-0011.
7. Singh J, Mohan A, Gupta K, Jain M, Varshney A. Categorization of pleural effusion specimen on the basis of the international system for reporting serous fluid cytopathology: an institutional experience. Int J Adv Res. 2024;12(11):1437-1442. doi: 10.21474/IJAR/0119960.
8. Chatterjee P, Sharma S, Jaiswal N, Bansal R, Khare A, Kansal Tiwari A. Comparison of body fluid cell counting between automated hematology analyzer and manual microscopic method. Int J Sci Res. 2023;12(3):364-368. doi: 10.36106/ijsr.
9. Baig MA. Automated body fluid analysis: a comparative evaluation of diagnostic performance of Abbott Cell-Dyn Ruby and Sysmex XT- 2000i. Int J Biol Med Res. 2015;6(4):5236-5239.
10. Kolte S, Zaheer S, Aden D, Ranga S. Application of the international system for reporting serous fluid cytopathology on reporting various body fluids: experience of a tertiary care hospital. CytoJournal. 2022; 19:52. doi: 10.25259/Cytojournal_49_2021.
11. Nayak K, Dubey S, Dhruw D, Azad KL. Application of international system for reporting serous fluid cytopathology on reporting various body fluids: a single institutional experience at a tertiary care centre, Bastar. Eur J Cardiovasc Med. 2025;15(8):35-40. doi: 10.61336/ejcm/25-08-08.
12. Baria R, Bhalara R, Dhruva G, Jethwani D. An application of cytological serous effusions reporting by Indian Academy of Cytologists guidelines in a tertiary care hospital at Rajkot (Gujarat), India: one year study. J Contemp Clin Pract. 2025;11(5):752-756. doi: 10.61336/jccp/25-05- 103.
13. Aanif S, Gupta D. Cytological analysis of body fluids in a tertiary care hospital of Jammu region: a one-year retrospective observational study. JK Pract. 2025;30(1):29-35.
14. Siatkowski M, Dahyot S, Pestel-Caron M, Boyer S. Performance evaluation of UF-4000 body fluid mode for automated body fluid cell counting. Clin Chim Acta. 2022;531:152-156. doi: 10.1016/j.cca.2022.04.010.
15. Cho J, Oh J, Lee SG, Lee YH, Song J, Kim JH. Performance evaluation of body fluid cellular analysis using the Beckman Coulter UniCel DxH 800, Sysmex XN-350, and UF-5000 automated cellular analyzers. Ann Lab Med. 2020;40(2):122-130. doi: 10.3343/alm.2020.40.2.122.
16. Savcı Ü, Şahin M, Eser B, Kayadibi H. A comparison of manual hemocytometry and different modes of Mindray BC-6800 hematology analyzer for cell count in peritoneal and pleural fluids. Dicle Med J. 2020;47(2):278-285. doi: 10.5798/dicletip.755702.
17. Ivady G, Barath S, Szaraz-Szeles M, Kurti-G Szabo E, Kovacs K, Petruska E, Hevessy Z. Comparative evaluation of body fluid analysis by Sysmex XN hematology analyzers, CellaVision, manual microscopy and multicolor flow cytometry. Ann Clin Lab Sci. 2022;52(2):314-322.
18. Saini A, Sareen R, Gupta GN. High fluorescent cells on automated body fluid analysis as discriminator for malignant cell detection. South Asian J Cancer. 2023;12(3):257-262. doi: 10.1055/s-0043-1776287.
19. Yoon S, Kim HR. Analytical performance of the digital morphology analyzer Sysmex DI-60 for body fluid cell differential counts. PLoS One. 2023;18(7): e0288551. doi: 10.1371/journal.pone.0288551.
20. Chaturvedi S, Gupta GN, Faujdar M, Jain R, Sareen R. Body fluid analysis by automated Sysmex XN-1000: the way ahead. Int J Clinicopathol Correl. 2024;8(1):22-28. doi: 10.56501/intjclinicopatholcorrel.v8i1.1075.
21. Shin E, Hur M, Kim H, Lee G-H, Hong M-H, Nam M, Lee S. Performance assessment of Sysmex DI-60: is digital morphology analyzer reliable for white blood cell differentials in body fluids diagnostics? Diagnostics (Basel). 2024;14(6):592. doi:10.3390/diagnostics14060592.