RESEARCH PAPER

Utility Of Reagent Strips In Body Fluid Analysis For Diagnosis In Resource-Limited Settings

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ABSTRACT

Background: Body fluid examination by microscopy and biochemistry remains the gold standard for diagnosing meningitis, spontaneous bacterial peritonitis (SBP), and pleural effusion types. However, these methods require trained personnel and laboratory infrastructure that are often unavailable in resource-limited settings, leading to delayed diagnosis.

Aim: To assess the diagnostic utility of urine reagent strips for rapid bedside evaluation of cerebrospinal fluid (CSF), pleural fluid, and ascitic fluid, and correlate findings with conventional biochemical and cytological methods.

Methods: A prospective observational study was conducted at the Department of Pathology, Chettinad Hospital and Research Institute, over 5 months (October 2025 – January 2026). Eighty-one residual body fluid samples (CSF n=30, pleural n=19, ascitic n=32) were tested using 10-parameter urine reagent strips and compared with automated biochemical analysis and Neubauer chamber cell counts.

Results: Pleural fluid protein showed the best performance (sensitivity 100%, NPV 100%, accuracy 73.68%). CSF protein sensitivity was 66.67% with accuracy 56.67%. Ascitic fluid showed more variable results (protein accuracy 18.75%). Gender distribution: 58.7% male, 41.3% female.

Conclusion: Reagent strips are rapid, cost-effective bedside tools suitable for differentiating transudates from exudates and POCT (point of care test) screening for infectious processes, particularly in resource-limited settings.

Keywords: Cerebrospinal fluid, pleural fluid, ascitic fluid, reagent strips, leukocyte esterase, meningitis, spontaneous bacterial peritonitis, transudate, exudate, resource-limited settings.

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INTRODUCTION

Body fluid analysis is an indispensable component of clinical laboratory medicine. The examination of cerebrospinal fluid (CSF), pleural fluid, and ascitic fluid provides critical diagnostic information across a wide spectrum of conditions, including life-threatening infections, malignancies, autoimmune disorders, and metabolic disturbances. The accurate and timely analysis of these fluids can significantly alter clinical management, guide therapeutic decisions, and influence patient outcomes. [1] Despite the established importance of body fluid

analysis, its practical implementation remains hampered in resource-limited settings by the significant dependence on trained laboratory personnel, specialized equipment, and reagent availability, however, these conditions that are frequently absent in peripheral, rural, and low-income healthcare environments. [2,3]

Moreover, Meningitis remains one of the most urgent medical emergencies encountered in clinical practice. It is a severe inflammation of the meninges, usually caused by bacterial, viral, fungal, or tuberculous pathogens. In particular, Bacterial meningitis, carries a high case fatality rate that is directly proportional to the delay in initiating appropriate antimicrobial therapy. Even in survivors, the risk of serious long-term neurological sequelae including hearing loss, cognitive impairment, epilepsy, and motor deficits is considerable. [4] The cornerstone of meningitis diagnosis is CSF examination, which includes measurement of opening pressure, gross appearance, total and differential cell count, glucose, protein, lactate, Gram stain, and culture. Each of these parameters contributes to establishing whether an infection is present, its likely causative organism, and its severity. However, CSF analysis by conventional laboratory methods demands an experienced microscopist for accurate cell counting, a functioning biochemistry analyser for glucose and protein estimation, and a microbiology laboratory for culture and sensitivity testing. In settings where these resources are unavailable or where turnaround time is prolonged, empirical treatment may be initiated without adequate diagnostic confirmation, leading to inappropriate antibiotic use and suboptimal outcomes. [3,5,6]

On other hand, Pleural effusion is another extremely common clinical presentation that poses significant diagnostic challenges. It is defined as the pathological accumulation of fluid in the pleural space and may result from a diverse range of etiologies including cardiac failure, hepatic cirrhosis, nephrotic syndrome, malignancy, tuberculosis, parapneumonic infection, pulmonary embolism, and autoimmune conditions. The clinical management of pleural effusion is fundamentally guided by whether the fluid is a transudate or an exudate. Transudates arise from systemic alterations in hydrostatic or oncotic pressure and are typically managed by treating the underlying systemic condition, whereas exudates result from local pleural inflammation or injury and require further evaluation and specific treatment. This distinction is classically made using Light's criteria, which rely on the ratios of protein and lactate dehydrogenase (LDH) between the pleural fluid and serum. [9] Beyond this basic categorization, exudative effusions must be further evaluated to determine whether they are infectious. In these cases procedure like drainage, pleural fluid culture, and antibiotic therapy become necessary. The entire diagnostic algorithm hinges on the availability of laboratory infrastructure to measure protein, LDH, glucose, and differential cell counts reliably, all of which require a functioning laboratory. [9,10]

Spontaneous bacterial peritonitis (SBP) is a serious and potentially fatal infectious complication that occurs predominantly in patients with advanced liver cirrhosis and ascites. It is defined by the presence of a polymorphonuclear neutrophil (PMN) count exceeding 250 cells/mm³ in ascitic fluid, often in association with a positive bacterial culture, in the absence of a surgically treatable intra-abdominal source. SBP develops as a consequence of impaired immune defences in the ascitic fluid, reduced phagocytic activity of peritoneal macrophages, and bacterial translocation from the gut in the setting of portal hypertension and intestinal dysbiosis. [11,12,13] The clinical presentation of SBP can be subtle and non-specific, and patients may present with fever, abdominal pain, and deterioration of liver function, or may be entirely asymptomatic. This makes clinical diagnosis unreliable and laboratory confirmation essential. [14] Early diagnosis and prompt initiation of intravenous antibiotics are critical to reducing morbidity and mortality; delays in diagnosis have been associated with a significantly higher in-hospital mortality. [15,16] However, the gold standard diagnostic approach, ascitic fluid PMN count by manual microscopy and culture will requires trained laboratory personnel, appropriate culture media, and incubation facilities, none of which are consistently available in low-resource settings. [11,12]

Urine reagent strips (dipsticks), originally designed for routine urinalysis, detect glucose, protein, leukocyte esterase, nitrite, pH, ketones, bilirubin, urobilinogen, blood, and specific gravity through a series of colorimetric chemical reactions on impregnated cellulose pads. Leukocyte esterase is an enzyme released by activated neutrophils and granulocytes, making its detection a semi-quantitative surrogate marker of cellular activity in any fluid. Glucose and protein pads similarly provide semi-quantitative estimates based on enzyme-mediated or protein-error colorimetric reactions. These strips are inexpensive, require no instrumentation, yield results within one to two minutes, are stable at room temperature, and can be used by personnel with minimal laboratory training. [5,6,7] If these strips can be validated for use in body fluids other than urine, they have the potential to serve as powerful point-of-care tools in emergency departments, primary care centres, and resource-limited hospitals

across the developing world, enabling rapid preliminary classification of body fluids while formal laboratory analysis is arranged. [1,7,8]

Several studies conducted in diverse settings have explored the utility of urine reagent strips in CSF analysis for the rapid diagnosis of meningitis, and in pleural and ascitic fluid analysis for the rapid identification of exudative and infectious pathology. [5-16] The published literature reports variable sensitivity and specificity values, partly reflecting differences in the strip brands used, the patient populations studied, and the reference standards applied. There is a need for prospective studies conducted in Indian tertiary care settings to validate the diagnostic utility of these strips across all three major body fluid types simultaneously. The present study was therefore designed to determine whether the semi-quantitative assessment of leukocyte esterase, protein, and glucose by urine reagent strips accurately correlates with standard biochemical and cytological analysis of CSF, pleural fluid, and ascitic fluid in a single institution, and to evaluate the feasibility of integrating reagent strip testing into routine body fluid analysis at the bedside.

MATERIALS AND METHODS

Study Design: Prospective observational study.

Setting: Department of Pathology, Chettinad Hospital and Research Institute, Kelambakkam, Tamil Nadu.

Duration: October 2025 – January 2026 (5 months).

Sample Size: 81 residual body fluid samples — CSF (n=30), pleural fluid (n=19), ascitic fluid (n=32).

Inclusion Criteria: Residual diagnostic samples with adequate volume processed on the same day of collection.

Exclusion Criteria: Grossly haemorrhagic samples, inadequate quantity for both tests, and leaky or delayed transport samples.

Index Test: Ten-parameter urine reagent strips were used to assess leukocyte esterase, glucose, and protein. Two to three drops of undiluted body fluid were applied to the strip pads and read at 120 seconds (leukocytes), 60 seconds (protein), and 30 seconds (glucose) per manufacturer instructions. [5,6,7]

Reference Standard: Glucose was estimated by hexokinase method and protein by biuret method on an Abbott automated analyser. Total and differential cell counts were performed using a Neubauer chamber and Giemsa-stained centrifuged smears. [2,3]

Statistical Analysis: Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were calculated for each parameter and fluid type.

RESULTS

The study included 81 body fluid samples. A total of 30 CSF samples, 19 pleural fluid samples, and 32 ascitic fluid samples were analysed. The demographic and fluid distribution details are presented below.

1. Demographic Profile

Of the 81 patients enrolled in the study, 47 (58.7%) were male and 33 (41.3%) were female.. The mean age differed across fluid types. CSF patients were the youngest (mean 35.67 years, median 42.50 years), reflecting the higher incidence of meningitis in younger age groups. Pleural fluid patients had a mean age of 46.53 years. Ascitic fluid patients were the oldest on average (mean 51.69 years, median 53.50 years), consistent with the peak prevalence of chronic liver disease in the fifth decade of life (Table 1).

Fluid type	Mean age(years)	Median age(years)	Standard Deviation
Ascitic fluid	51.69	53.50	11.56
CSF	35.67	42.50	22.09
Pleural fluid	**46.53**	**45.00**	**15.50**

Table 1: Age distribution by fluid type

2. Fluid Analysis

Table 2: Association of Leukocyte Esterase with Protein and Glucose in Different Body Fluids

Fluid Type	Parameter		Leukocyte Esterase Positive	Leukocyte Esterase Negative	Total
Ascitic Fluid	**Protein**	Protein Positive	3	23	26
		Protein Negative	3	3	6
		Total	6	26	32
	Glucose	Glucose Positive	3	24	27
		Glucose Negative	3	2	5
		Total	6	26	32
CSF	**Protein**	Protein Positive	6	10	16
		Protein Negative	3	11	14
		Total	9	21	30
	Glucose	Glucose Positive	5	14	19
		Glucose Negative	4	7	11
		Total	9	21	30
Pleural Fluid	**Protein**	Protein Positive	11	5	16
		Protein Negative	0	3	3
		Total	11	8	19
	Glucose	Glucose Positive	11	0	11
		Glucose Negative	6	2	8
		Total	17	2	19

The table 2 presents the association between leukocyte esterase activity and biochemical parameters (protein and glucose) across three different body fluids—ascitic fluid, cerebrospinal fluid (CSF), and pleural fluid.

In **ascitic fluid**, leukocyte esterase positivity was observed equally among protein-positive and protein-negative samples (3 cases each), whereas the majority of leukocyte esterase-negative cases were protein positive (23 out of 26). A similar distribution was noted with glucose, where leukocyte esterase-positive cases were equally divided between glucose-positive and glucose-negative groups (3 cases each), while most leukocyte esterase-negative cases were glucose positive (24 out of 26).

In **CSF**, among protein-positive samples, 6 cases showed leukocyte esterase positivity compared to 10 cases that were negative. In protein-negative samples, leukocyte esterase positivity was lower (3 cases) compared to negativity (11 cases). With respect to glucose, 5 glucose-positive samples were leukocyte esterase positive, while 14 were negative. Among glucose-negative samples, leukocyte esterase positivity (4 cases) was slightly lower than negativity (7 cases).

In **pleural fluid**, a strong association was observed between protein positivity and leukocyte esterase positivity, with 11 out of 16 protein-positive samples showing leukocyte esterase positivity, while none of the protein-negative samples were leukocyte esterase positive. Regarding glucose, all glucose-positive samples (11 cases)

demonstrated leukocyte esterase positivity, whereas among glucose-negative samples, 6 were leukocyte esterase positive and 2 were negative.

Overall, leukocyte esterase positivity demonstrated variable associations with protein and glucose levels across different body fluids, with a notably stronger association observed in pleural fluid compared to ascitic fluid and CSF.

3. Diagnostic Performance Across All Fluid Types

Table 3 presents a consolidated summary of the diagnostic performance of reagent strips for all three fluid types and both parameters. Overall, pleural fluid analysis yielded the strongest results, with the best sensitivity and NPV for protein, and perfect specificity and PPV for glucose. CSF showed moderate performance for protein, while glucose analysis was limited by the inherent technical constraints of the strip detection threshold. Ascitic fluid showed the most variable results, with low specificity and accuracy across both parameters.

Table 3: Diagnostic performance across all fluid types and parameters

Fluid / Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV(%)	Accuracy (%)
Ascitic — Protein	50.0	11.5	11.5	50.0	18.75
Ascitic — Glucose	50.0	7.6	11.1	40.0	15.63
CSF — Protein	66.67	52.38	37.5	78.5	56.67
CSF — Glucose	55.56	33.33	26.32	63.64	40.00
Pleural — Protein	100.0	37.5	68.75	100.0	73.68
Pleural — Glucose	64.71	100.0	100.0	25.0	68.42

DISCUSSION

The present study evaluated the diagnostic utility of urine reagent strips as a rapid bedside tool for the semi-quantitative assessment of leukocyte esterase, protein, and glucose in three distinct body fluid compartments that is ascitic fluid, cerebrospinal fluid, and pleural fluid. A total of 81 samples were analyzed over a five-month period at a tertiary care centre. The study population showed a male predominance (58.7%), which is consistent with the well-established epidemiological trends for the underlying diseases presenting with these fluid abnormalities. Cirrhotic liver disease, which predisposes to ascites and SBP, as well as pulmonary tuberculosis leading to pleural effusion, are both significantly more prevalent in males in South Asian populations. The youngest patients were in the CSF group (mean age 35.67 years), reflecting the higher burden of meningitis in children and young adults. The oldest patients were in the ascitic fluid group (mean age 51.69 years), in keeping with the peak incidence of chronic liver disease in the fifth decade of life.

The findings of this study clearly demonstrate that the diagnostic performance of reagent strips varies substantially across the three fluid types and between the two parameters evaluated. This variability is not unexpected, as the strips were originally designed and calibrated for use in urine, and their application to body fluids involves assumptions about the chemical matrix that may not always hold. A systematic understanding of where the strips perform well and where they fall short is essential before integrating them into clinical practice. The discussion below addresses each fluid type and parameter in turn, before examining the overarching implications of these findings for clinical practice in resource-limited settings.

Among the three fluid types studied, pleural fluid emerged as the compartment in which reagent strips performed best. The leukocyte esterase-protein correlation for pleural fluid demonstrated a sensitivity and NPV of 100%, meaning that the strip identified every case of elevated pleural protein without a single false negative. This makes the reagent strip an exceptionally reliable negative screening test for pleural protein: if the strip is negative, the clinician can be highly confident that pleural protein is not elevated, and the effusion is unlikely to be an exudate. This property is particularly valuable in settings where formal laboratory analysis is unavailable overnight or on weekends, allowing clinicians to provisionally categories an effusion and plan appropriate initial management without delay. [10] The moderate specificity of 37.5% for pleural protein means that a positive result must be interpreted with caution, as it may be a false positive, but this is an acceptable limitation for a preliminary bedside

screening test. The 100% specificity and PPV for pleural glucose are equally noteworthy, confirming that when the strip returns a positive glucose result in pleural fluid, this invariably corresponds to a true abnormality. The combination of 100% sensitivity and NPV for protein alongside 100% specificity and PPV for glucose gives clinicians a powerful, complementary two-parameter bedside assessment: a negative protein strip effectively rules out an exudate, while a positive glucose strip firmly implicates an infectious process. [10]

The performance of reagent strips in CSF analysis was moderate across both parameters. For protein, the sensitivity of 66.67% and NPV of 78.5% suggest that the strip is clinically useful but not comprehensive: it correctly identifies raised CSF protein in roughly two-thirds of cases and provides some reassurance when negative, though it cannot exclude raised protein with confidence. The moderate specificity (52.38%) and accuracy (56.67%) reflect a significant false-positive rate, which may partly result from borderline protein elevations falling around the strip's detection threshold, as well as non-specific colorimetric interference from other CSF constituents. The most important limiting factor for CSF leukocyte esterase analysis is its granulocyte specificity. The leukocyte esterase reaction detects esterase activity released by activated neutrophils and does not respond to lymphocytes, monocytes, or other mononuclear cells. In conditions where CSF pleocytosis is dominated by lymphocytes — as in viral meningitis, tuberculous meningitis, fungal meningitis, and partially treated bacterial meningitis — the strip may return to a falsely negative result despite a markedly elevated total cell count. [5,6] This represents a fundamental biological limitation that cannot be overcome by adjusting the strip's detection threshold and underscores the continued importance of microscopic cell counting in CSF analysis. Despite this, the strip's value lies in its ability to provide an immediate, reagent-free assessment of likely neutrophilic pleocytosis in acute bacterial meningitis, where granulocytes typically predominate and where every minute of diagnostic delay increases the risk of adverse outcomes. [4,7,8]

CSF glucose analysis using the reagent strip yielded the lowest accuracy in this study (40%), primarily due to the mismatch between the strip's detection threshold and the clinically relevant range for CSF glucose. Standard urine strips detect glucose at a threshold of less than 100 mg/dL, whereas the normal CSF glucose range is 45–80 mg/dL. This means the strip's detection window begins at a value that is already at the upper limit of normal CSF glucose, making it essentially unable to distinguish between normal and mildly reduced glucose, the very gradient that is diagnostically meaningful in bacterial meningitis, where CSF glucose commonly falls to 20–40 mg/dL. While severely hypoglycorrhachia (glucose <20 mg/dL) would still be detected by the strip as a negative glucose result, mild to moderate reductions, which are the most common presentations of early or partially treated meningitis, would be missed. [6] The low PPV (26.32%) for CSF glucose is also concerning, as it means that even when the strip returns a positive result, it is more likely to be a false positive than a true reflection of elevated glucose in the context of a normal to borderline CSF glucose level. Strips from manufacturers who have calibrated their glucose pad to detect at a lower threshold (<50 mg/dL) would substantially improve the diagnostic utility for CSF glucose analysis, and this is an important area for future development. [6,7]

Ascitic fluid analysis demonstrated the most variable and generally weakest performance across all parameters in this study. The low specificity for both protein (11.5%) and glucose (7.6%) resulted in large numbers of false positives, contributing to the poor overall diagnostic accuracy of 18.75% and 15.63% respectively. Several factors may explain this performance. First, ascitic fluid has a much more complex and variable biochemical composition than urine or even CSF. It contains significant amounts of albumin, bilirubin, fibrinogen degradation products, cellular debris, and occasionally blood products, depending on the aetiology of the ascites. Many of these substances can cause non-specific colorimetric reactions on the protein and glucose pads of the strip, which are designed to respond to very specific chemical interactions calibrated for a urine matrix. [17] Bilirubin is known to interfere with leukocyte esterase reactions on urine strips, and high concentrations of albumin can cause protein pad reactions independent of the total protein level by standard biochemical methods. Second, the polymorphonuclear cell count in ascitic fluid that defines SBP (>250 cells/mm³) may not always correlate with sufficient leukocyte esterase activity to trigger a positive strip reaction, particularly in early or treated infection, or in the presence of spontaneous resolution. [18] Third, the normal glucose range in ascitic fluid (70–100 mg/dL) overlaps substantially with urinary glucose norms, but the dynamic range of glucose changes in infected ascitic fluid is narrower than in urine, making strip-based glucose detection less discriminating. Despite these limitations, the sensitivity of 50% for leukocyte esterase in ascitic fluid is not without value. In a setting where no PMN count or cell count is available, even a 50% sensitive rapid test can meaningfully change clinical management by prompting empirical antibiotic therapy in high-risk patients while formal tests are being arranged. [18,20] Future

development of ascitic-fluid-specific strips that incorporate a pan-leukocyte marker (detecting both neutrophils and lymphocytes) and are calibrated for the expected protein and glucose ranges of ascitic fluid rather than urine would represent a significant advance in point-of-care diagnostics for SBP. [19,20]

A key strength of the present study is its simultaneous evaluation of all three fluid types in a single institution using a standardised protocol, which allows direct comparison of strip performance across compartments under identical conditions. The study also reflects a real-world patient population from a South Indian tertiary care centre, making its findings directly applicable to similar resource-constrained settings across the subcontinent. The principal limitation of the study is the modest sample size, particularly for pleural fluid and ascitic fluid, which means that confidence intervals around the reported sensitivity, specificity, PPV, and NPV values would be wide, and the findings should be interpreted as preliminary. A larger multicentre study with a more balanced distribution of infected and non-infected samples within each fluid category would provide more robust estimates. Additionally, the study could not evaluate the reagent strip performance for synovial fluid or for less common body fluid compartments due to the limited number of samples received during the study period. Future studies should also explore whether combining two or more strip parameters — for example, a positive leukocyte esterase combined with a negative glucose — in a composite diagnostic algorithm improves accuracy over single-parameter analysis.

CONCLUSION

Urine reagent strips are simple, inexpensive, and rapid bedside tools that can meaningfully contribute to the diagnosis of conditions affecting body fluids, particularly in resource-limited settings. Pleural fluid analysis demonstrated the strongest performance, with 100% sensitivity and NPV for protein and 100% specificity and PPV for glucose, making reagent strips a reliable first-line screen for exudative and infectious pleural effusions.CSF analysis showed moderate performance that is still clinically useful in emergency settings, particularly where automated laboratory analysis is unavailable or delayed. Ascitic fluid results were more variable; however, the rapid bedside POCT (Point of care testing) nature of the test still provides utility as an initial screen for SBP.

Limitations

The main limitations of current reagent strips for body fluid analysis are the granulocyte-specific nature of the leukocyte esterase reaction, the high glucose detection threshold, and calibration for urinary rather than body fluid matrices. Designing body-fluid-specific strips with lower glucose cut-offs and pan-leukocyte markers would substantially improve their diagnostic accuracy. If implemented widely in peripheral and rural health centers, reagent strip testing of body fluids has the potential to reduce diagnostic turnaround time and enable earlier initiation of life-saving treatment for meningitis and spontaneous bacterial peritonitis.

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