RESEARCH NOTE

Performance of Lipoarabinomannan Assay using Cerebrospinal fluid for the diagnosis of Tuberculous meningitis among HIV patients [version 1; peer review: 2 approved]

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Abstract

**Background:** The diagnostic utility of the *Mycobacteria tuberculosis* lipoarabinomannan (TB-LAM) antigen lateral flow assay on cerebrospinal fluid (CSF) for the diagnosis of tuberculous meningitis (TBM) has not been extensively studied and the few published studies have conflicting results.

**Methods:** Lumbar CSF from 59 HIV-positive patients with suspected TBM was tested with TB-LAM and Xpert MTB/Rif Ultra. The diagnostic performance of CSF TB-LAM was compared to positive CSF Xpert MTB/Rif Ultra (definite TBM) and a composite reference of probable or definite TBM according to the uniform case definition.

**Results:** Of 59 subjects, 12 (20%) had definite TBM and five (9%) had probable TBM. With reference to definite TBM, CSF TB-LAM assay had a diagnostic sensitivity of 33% and specificity of 96%. When compared to a composite reference of definite or probable TBM, the sensitivity was 24% and specificity was 95%. There were two false positive tests with TB-LAM (3+ grade). In-hospital mortality in CSF TB-LAM positive patients was 17% compared to 0% in those with definite TBM by Xpert MTB/Rif Ultra but negative LAM.

**Conclusions:** Lumbar CSF TB-LAM has a poor performance in diagnosing TBM. Both urine TB-LAM and Xpert Ultra should be further investigated in the diagnosis of TBM.

**Keywords**

Tuberculous meningitis, extra-pulmonary TB, lipoarabinomannan, TB-LAM, Xpert MTB/Rif Ultra, HIV, Diagnostics, cerebrospinal fluid

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**Open Peer Review**

**Reviewer Status**

Invited Reviewers

| 1 | 2 |
|---|---|
| **version 1**
| published 19 Aug 2019
| report | report |

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Any reports and responses or comments on the article can be found at the end of the article.
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Competing interests: No competing interests were disclosed.

Grant information: This work was supported by the Wellcome Trust [107742, 107743 and 210772]. This research was also supported in part by the National Institute of Neurologic Diseases and Stroke (NINDS) and Fogarty International Center [R01NS086312, K01TW010268]. DBM and RK are currently supported through the DELTAS Africa Initiative grant [DEL-15-011] to THRiVE-2, from Wellcome Trust grant [107742] and the UK government. FVC is supported through a Wellcome Clinical PhD Fellowship [210772]. FVC is an honorary fellow of the Makerere University – UVRI Centre of Excellence for Infection and Immunity Research and Training (MUII-plus). MUII-plus is supported through the DELTAS Africa Initiative [107743]. The DELTAS Africa Initiative is an independent funding scheme of the African Academy of Sciences (AAS), Alliance for Accelerating Excellence in Science in Africa (AESA) and supported by the New Partnership for Africa’s Development Planning and Coordinating Agency (NEPAD) with funding from the Wellcome Trust [107743] and the UK Government. The MRC/UVRI and LSHTM Uganda Research Unit is jointly funded by the UK Medical Research Council (MRC) and the UK Department for International Development (DFID) under the MRC/DFID Concordat agreement and is also part of the EDCTP programme supported by the European Union.

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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How to cite this article: Kwizera R, Cresswell FV, Mugumya G et al. Performance of Lipoarabinomannan Assay using Cerebrospinal fluid for the diagnosis of Tuberculous meningitis among HIV patients [version 1; peer review: 2 approved] Wellcome Open Research 2019, 4:123 (https://doi.org/10.12688/wellcomeopenres.15389.1)

First published: 19 Aug 2019, 4:123 (https://doi.org/10.12688/wellcomeopenres.15389.1)
Introduction

In many human immunodeficiency virus (HIV) endemic countries, tuberculous meningitis (TBM) is the second most common cause of adult meningitis after cryptococcal meningitis\(^3\), and accounts for 1–5% of all tuberculosis (TB) cases\(^1\). TBM is the most severe form of TB and causes substantial morbidity and mortality in children and immunocompromised adults\(^1\). HIV infection is known to increase the risk of death in patients with TBM, as does TBM stage at the time of treatment initiation\(^1\). As is the case in cryptococcosis, high-quality nursing care is a critical component in managing TBM patients\(^6\).

Similarly, diagnosis of TBM is very challenging, especially in resource-limited settings where diagnosis relies on a combination of clinical, radiological and laboratory findings. The World Health Organisation (WHO) recommends Xpert MTB/RIF Ultra for the diagnosis of TBM using cerebrospinal fluid (CSF). Culture has many limitations related to turnaround time and sensitivity, and also requires considerable infrastructure and costs\(^1\). Therefore, the development of early point of care diagnosis for TBM is a priority. Recent studies have demonstrated that the next generation Xpert MTB/RIF Ultra is the most sensitive diagnostic test in HIV-positive adults\(^1\). However, Xpert MTB/RIF Ultra is not a bedside test, and thus access to same day results remain a challenge in many settings\(^1\).

Assays based on the detection of mycobacterial lipoarabinomannan (TB-LAM) antigen in urine have emerged as potential point-of-care tests for extra-pulmonary TB. There is evidence that urine TB-LAM may help to reduce mortality and predict poor outcomes\(^2,3\). The WHO recently added the TB-LAM assay onto its essential diagnostic list and recommended TB-LAM in hospitalised HIV positive adults with signs and symptoms of TB\(^1\). However, there are conflicting results about TB-LAM assay sensitivity for TBM diagnosis\(^6\) in CSF. With reference to definite TBM, Cox et al. found a 75% sensitivity using CSF from the fourth ventricle in an autopsy cohort from 91 HIV-infected adults\(^6\). However, Bahr et al. had no positive TB-LAM tests using lumbar CSF from 67 HIV patients with meningitis\(^1\). In light of these results, and now that Xpert MTB/RIF Ultra is used instead of Xpert MTB/RIF, we aimed to further explore the utility of CSF TB-LAM test for the diagnosis of TBM among HIV-positive adults presenting with suspected meningitis.

Methods

Study setting and participants

Between April 2018 and June 2019, we assessed and performed diagnostic lumbar punctures on HIV-positive patients admitted to Mulago National Referral Hospital with suspected meningitis in Kampala, Uganda. Screening for TBM was performed cross-sectionally as part of the High Dose Rifampicin for Tuberculous Meningitis (RIFT) trial (ISRCTN registration number ISRCTN42218549, last updated 24/04/2018)\(^1\). Therefore, we did not calculate a sample size for the current study but included all participants that fit the screening criteria for the RIFT trial\(^1\). All included participants were HIV-infected adults (≥18 years old) who provided written informed consent by participant or surrogate, with a suspected diagnosis of TBM (meningitis symptoms, clinical signs of meningism). Demographic information and baseline characteristics for participants were collected through clinical reviews using customized meningitis screening case report forms approved by the relevant ethics committees (Mulago Hospital Research Ethics Committee, Uganda National Council of Science and Technology, and the University of Minnesota). Opening pressures for CSF were measured using a manometer, followed by standard microbiology analysis (CrAg, cell count, protein, glucose, lactate, culture).

Diagnostic tests

In addition to standard microbiology analysis, CSF was tested with TB-LAM (Alere, Massachusetts, USA), and the test strip interpreted as per manufacturer’s instructions. Briefly, the protective foil cover was removed from each test and the strip labelled with the participant’s number. Two drops (or 60μL) of CSF were added to the sample pad. The test was then read after 25 minutes under standard indoor lighting conditions. The reference card was used in interpretation of the results by holding it alongside the patient window. For positive results, purple/gray bars appeared in both the control window and the patient window of the strip. For negative results, one purple/gray bar appeared in the control window of the strip and no bar appeared in the patient window of the strip. If there was no bar in the control window of the strip, the result was considered invalid and the test repeated. The strips were retained and cross checked by a second researcher to corroborate the finding.

CSF was also tested with Xpert MTB/Rif Ultra (Cepheid). Briefly, 2ml of sample reagent was added to 1ml of whole CSF and then left to stand at room temperature for 15 minutes. Then, 2ml of the sample mixture was transferred into the Xpert MTB/Rif Ultra cartridge and loaded into the Xpert machine. The test was run for 90 minutes and results from the assay indicate whether or not Mycobacteria TB (MTB) was detected in the sample. If MTB was detected, the results also stated whether resistance to rifampin was detected.

Test analysis

Data were analyzed using STATA version 14 (STATA, College Station, Texas). The disease prevalence, sensitivity, specificity, positive predictive values, negative predictive values and test accuracy were estimated at 95% confidence interval (CI). The diagnostic performance of CSF TB-LAM was compared to positive CSF Xpert MTB/Rif Ultra (definite TBM) and a composite reference of probable or definite TBM according to the uniform case definition\(^6\). Summaries were made in frequency & percentages for each baseline characteristic considered as a categorical, and medians (interquartile range) when each characteristic is considered as a continuous variable. For baseline variables with some missing data, we calculated the statistics using the available numbers.

Ethical statement

Institutional review board approvals for the study and the associated screening process were obtained locally in Uganda (Mulago Hospital Research Ethics Committee, approval number...
MREC 1260); and from the London School of Hygiene and Tropical Medicine, UK (14388), University of Minnesota (1304M31361) and by the Uganda National Council of Science and Technology (HS136ES). Written informed consent for participation in the study and data publication was obtained from all participants or from their surrogates (e.g. family member or guardian) where the patient had altered mental status and did not have the capacity to provide consent.

Results
Overall, 59 HIV-positive hospitalized participants with suspected meningitis underwent diagnostic lumbar punctures, of which 20% (12/59) had definite TBM, 9% (5/59) had probable TBM, 25% (15/59) had possible TBM, and 46% (27/59) had no-TBM. Of those with no TBM (n=27), 10 had cryptococcosis. Women comprised 50% of participants with an overall median age for all participants of 33 years (interquartile range [IQR]: 28, 40). Only 29% of the participants were receiving antiretroviral therapy at diagnosis. Among participants reporting a headache (n=57), the median duration of headache was 14 days (IQR: 14, 24). The CSF opening pressures at baseline (n=45) had a median of 200 mmH_2O (IQR: 120, 260). Overall, 55% (n=36) had an acellular CSF, whilst those with a CSF lymphocytic pleocytosis had a median CSF white blood cell of 160 cells/μL (IQR: 135, 268) (Table 1).

With respect to the reference standard of definite TBM (positive CSF Xpert TB/Rif Ultra), the CSF TB-LAM assay had a sensitivity of 33% (4/12), specificity of 96% (45/47), positive predictive value (PPV) of 67% (4/6), and negative predictive value (NPV) of 85% (45/53). When compared to a composite reference of definite/probable TBM, the TB-LAM assay had a sensitivity of 24% (4/17), specificity of 95% (40/42), PPV of 67% (4/6), NPV of 76% (40/53) (Table 2). There were two false positive tests with TB-LAM (3+ grade), without any CSF pleocytosis, normal protein, normal glucose, negative cryptococcal antigen, and normal CSF opening pressure. One patient was discharged alive without TB therapy. The second patient had a headache for 60 days at presentation, but they were lost to follow up (i.e. self-discharged) without an etiologic diagnosis. In-hospital mortality in CSF TB-LAM positive patients was 17% (1/6) compared to 0% (0/8) in those with definite TBM by Xpert MTB/Rif Ultra but negative LAM.

| Table 1. Characteristics of the study population. |
|-----------------------------------------------|
| **Baseline characteristics**                  |
| **Data available for**                        |
| **Statistic**                                  |
| **N participants**                             |
| **Women, n (%)**                              | 58 | 29 (50) |
| **Age in years, median (IQR)**                | 58 | 33 (28-40) |
| **On ART, n (%)**                             | 47 | 29 (62) |
| **Headache, n (%)**                           | 57 | 46 (81) |
| **Duration of headache, median (IQR) days**   | 45 | 14 (14-24) |
| **Glasgow Coma Scale score, mean (SD)**       | 55 | 13 (2.6) |
| **CSF crag positive, n (%)**                  | 58 | 10 (17) |
| **CSF Opening Pressure, median (IQR) mmH_2O** | 45 | 200 (120-260) |
| **Acellular CSF, n (%)**                      | 55 | 36 (55) |
| **CSF WBC in those with CSF WBC pleocytosis, median (IQR) cells/μL** | 55 | 160 (135-268) |
| **CSF protein, median (IQR) mg/dL**           | 52 | 57 (28-141) |
| **CSF glucose, median (IQR) mg/dL**           | 32 | 65 (34-82) |
| **CSF lactate, median (IQR) mmol/L**          | 36 | 3.9 (2.2-9) |
| **Duration of hospitalization, median (IQR) days** | 46 | 7 (4-14) |
| **Status at discharge**                       |
| **Alive, n (%)**                              | 59 | 40 (68) |
| **Dead, n (%)**                               | 9 (15) |
| **Unknown, n (%)**                            | 10 (17) |

Data presented are percentages (%), medians and interquartile ranges (IQR). N= number of participants with data for each parameter. *Some parameters have N<59 due to missing data. ART = antiretroviral therapy, CSF = cerebrospinal fluid, WBC = white blood cells.
### Table 2. Summary of diagnostic performance of cerebrospinal fluid mycobacterial lipoarabinomannan assay for tuberculous meningitis.

| Reference standard       | Disease prevalence | Sensitivity | Specificity | PPV  | NPV  | Test Accuracy |
|--------------------------|-------------------|-------------|-------------|------|------|---------------|
| Definite/probable TBM    | 28.8% (17/59)     | 23.5% (4/17) | 95.2% (40/42) | 66.7% (4/6) | 75.5% (40/53) | 74.6% (44/59) |
| 95% CI                   | 17.8 to 42.1%     | 6.8 to 49.9% | 83.8 to 99.4% | 28.7 to 90.8% | 70.1 to 80.2% | 61.6 to 85% |
| Definite TBM             | 20.3% (12/59)     | 33.3% (4/12) | 95.7% (45/47) | 66.7% (4/6) | 84.9% (45/53) | 83.1% (49/59) |
| 95% CI                   | 10.9 to 32.8%     | 9.9 to 65.1% | 85.5 to 99.5% | 29.3 to 90.6% | 78.9 to 89.4% | 71 to 91.6% |

Data presented are the percentage, numerator/denominator, and 95% confidence intervals (CI). Test Accuracy = overall probability that a patient will be correctly classified. PPV = Positive predictive value, NPV = negative predictive value, TBM = tuberculous meningitis.

### Conclusion

In conclusion, a rapid diagnosis of TBM could be achieved using a point of care test on CSF such as a TB-LAM antigen lateral flow assay; however, this study demonstrated a poor diagnostic performance of the existing Alere TB-LAM on CSF among HIV-associated tuberculous meningitis. While the relatively modest sample size is a limitation, a larger sample size is unlikely to fundamentally alter the findings of sensitivity. One explanation could be that TB-LAM is likely not be found in sufficient quantities in lumbar CSF. Further studies are required using larger number of cases to investigate the utility of urine TB-LAM in aiding the diagnosis of probable TBM or the diagnostic performance of the next generation of TB-LAM assay.

### Data availability

**Underlying data**

Figshare: CSFLAM_data set revised.xlsx. [https://doi.org/10.6084/m9.figshare.9415853.v1](https://doi.org/10.6084/m9.figshare.9415853.v1)

Data are available under the terms of the Creative Commons Zero “No rights reserved” data waiver (CC0 1.0 Public domain dedication).

### Grant information

This work was supported by the Wellcome Trust [107742, 107743 and 210772]. This research was also supported in part by the National Institute of Neurologic Diseases and Stroke (NINDS) and Fogarty International Center [R01NS086312, K01TW010268]. DBM and RK are currently supported through the DELTAS Africa Initiative grant [DEL-15-011] to THRIVE-2, from Wellcome Trust grant [107742] and the UK government. FVC is supported through a Wellcome Clinical PhD Fellowship [210772]. FVC is an honorary fellow of the Makerere University – UVRI Centre of Excellence for Infection and Immunity Research and Training (MUII-plus). MUII-plus is supported through the DELTAS Africa Initiative [107743]. The DELTAS Africa Initiative is an independent funding scheme of the African Academy of Sciences (AAS), Alliance for Accelerating Excellence in Science in Africa (AESA) and supported by the New Partnership for Africa’s Development Planning and Coordinating Agency (NEPAD) with funding from the Wellcome Trust [107743] and the UK Government. The MRC/UVRI and LSHTM Uganda Research Unit is jointly funded by the UK Medical Research Council (MRC) and the UK Department for International Development (DFID) under the MRC/DFID Concordat agreement and is also part of the EDCTP2 programme supported by the European Union.

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

### Acknowledgements

We thank institutional support from the IDI research office.

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Current Peer Review Status: ✔ ✔

Version 1

Reviewer Report 16 September 2019

https://doi.org/10.21956/wellcomeopenres.16813.r36425

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Vinod Patel
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The article is well written with no major flaws.

Regarding the non-TBM category, although 10 patient had cryptococcal meningitis, detail regarding the non-TBM diagnoses is important as this is a control group and a patient without a clinical meningitis may allow for better specificity. I note that some CSF’s were acellular, what were these diagnoses?

Please provide detail (a table with confirmatory findings for TB such as CXR, abdominal ultrasound, scan findings, CSF findings etc.) regarding the aspects considered to arrive at a diagnosis of probable and possible TBM. A similar consideration for possible TBM. This would add clarity on the reliability of the test outcomes.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Assessing novel tests in the diagnosis of tuberculous meningitis.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

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Maryline Bonnet
Institute of Research for Development (IRD), Montpellier, France

This manuscript reports the results of a nested study in a large clinical trial, evaluating the accuracy of the CSF LAM for diagnosis of tuberculosis meningitis using both definite TB and composite reference of probable and definite TB based on standard case definitions. The study reports low sensitivity and high specificity and concludes on the modest role of the CSF LAM for diagnosis of TB meningitis. These results are important and the manuscript is well written.

No major comments.

Minor comments:
In the introduction, I suggest the authors adding the recent publication by Siddiqi *et al.* (2019) in their references.

In Results, I would suggest the authors to present the characteristics of patients with diagnosis of probable TB using the uniform case definitions. I am surprised by the low proportion of probable TB as compared to definite TB. It would be interesting to know the score of patients with probable TB using the uniform case definition criteria. Were cerebral imaging criteria used? It would be also interesting to know the proportion of patients that fit the score of possible TB meningitis using the uniform case definitions. It is indeed important to know the proportion of possible TB meningitis cases based on the uniform cases definitions that were finally classified as non TB meningitis for the accuracy analysis.

It would be interesting to know the proportion of patients with TB positive results from another specimen than CSF, which is also an important criteria for diagnosis of probable TB meningitis. One option could be to present the patients’ characteristics by definite TB, probable TB and others in Table 1.

How do the authors explain that 17% of patients had unknown outcome of death or alive at discharge? It is quite high in a context of a nested study in a clinical trial.

TB culture was not used, which is a limitation of the accuracy analysis. However, Xpert Ultra has a...
sensitivity that is very close to culture. This could be mentioned as a limitation.

It would be also very interesting to have the results of the urine LAM if used. In the study by Siddiqi et al. the urine LAM had higher sensitivity than the CSF LAM in patients with presumptive TB meningitis.

In the conclusion, the authors could mention the Fuji LAM that is a new LAM POC test that has higher sensitivity in urine than the determine LAM POC and should also be evaluated for diagnosis of TB meningitis both in urine and CSF.

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Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

*Competing Interests*: No competing interests were disclosed.

*Reviewer Expertise*: Clinical research on tuberculosis.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.