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GENEXPERT MTB/RIF DIAGNOSTIC AND TUBERCULOSIS TREATMENT INITIATION DELAYS IN NAMIBIA

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Namibia.

ABSTRACT

Background: Early diagnosis and treatment of drug resistant tuberculosis are crucial in the control of the disease and treatment success. In Namibia, there is a gap in empirical data on the diagnosis and treatment initiation delay time since the roll-out of the GeneXpert MTB/RIF (Xpert) assay in 2017. This study aimed to determine Xpert pre-diagnosis and turnaround time at Namibian Institute of Pathology (NIP) as well as rifampicin resistant tuberculosis (RR-TB) treatment initiation delay on patients admitted at Katutura Intermediate Hospital TB clinic. **Methods:** This was retrospective descriptive cross-sectional study which was conducted from 1 July 2018 to 31 March 2019. A total of seventy two participants comprising of twenty five RR-TB and forty seven non RR-TB patients were enrolled using consecutive sampling method. Laboratory information system (LIS) was utilized to determine Xpert median pre-analytical delay and turnaround time. Patients' records and LIS were used to calculate median treatment initiation delay time post Xpert diagnosis. Data on continuous variables was summarized as median and interquartile range**. Results:** The median pre-diagnostic, diagnostic and treatment initiation delay time were 7.5 (IQR: 0-14), 1 (IQR: 0-3) and 10 (IQR: 1-32) days respectively for RR-TB. For drug susceptible TB, the median pre-diagnostic, diagnostic and treatment initiation delay time were 5 (IQR: 1-8), 1 (IQR: 0-3) and 3 (IQR: 0-12) days respectively. Overall, median health system delay time was 21 (IQR: 2-32) days for RR-TB patients and 12 (IQR: 1-12) days for non RR-TB patients. **Conclusion**: Treatment initiation to appropriate second line regimes was long for many patients and may be attributable to poor interpretation of discordant results and increased number of RR-TB patients for treatment since Xpert adoption. Unnecessary referrals due to shortages of pulmonologists, cumbersome baseline investigations and outdated guidelines and policies could be the determinants of health system delay time. Interventions targeted at addressing identified factors should be implemented. Further studies should explore the actual treatment gap among RR-TB patients and further risk factors for delayed treatment.

KEYWORDS: Pre-analytical delay, Analytical delay, Rifampicin resistant tuberculosis, Treatment initiation, GeneXpert MTB/RIF assay.

BACKGROUND

Despite the global decrease in tuberculosis (TB) incidence and progress made in TB control in recent decades, drug resistant tuberculosis (DR-TB) is now a major global public health challenge. Drug resistant TB is a resultant of selection of naturally occurring genomic mutants and two modes of transmission has been postulated (Kambli *et al*., 2015). Firstly, primary DR-TB occurs from direct transmission of the resistant mutants from one person to another and this is the most predominant mode of transmission. Secondly, acquired DR-TB results from TB treatment at suboptimal levels as a result of weak health systems and care provision, TB drugs of poor quality, patient non-adherence and inadequate policies that support optimal treatment and service provision (World Health Organization, 2017). Prioritizing DR-TB diagnosis improves time to treatment initiation. World Health Organization (WHO) recommends Xpert MTB/RIF assay (Xpert) for rapid diagnosis of rifampicin resistance and susceptible TB. Since 2011, Albert and colleagues (2016) aver that global roll-out of rapid Xpert assay has increased case detection of RR-TB compared to longer conventional drug resistant testing methods.

In Namibia, Xpert was recently rolled out, targeting patients at risk of rifampicin resistant TB, followed by

molecular line probe assay (LPA) and phenotypic drug-susceptibility testing (DST). To our knowledge, there is no empirical evidence on health system delays in diagnosis and treatment initiation since Xpert decentralization in 2017. This gap compelled this descriptive retrospective study to determine diagnostic and treatment initiation delay time post diagnosis.

Rapid and accurate diagnosis of TB and DR-TB in all population groups, including people living with HIV (PLHIV) and children is essential in reducing drug susceptible and resistant TB transmission, morbidity and mortality. This is a significant benefit to health system delivery, patients and communities. Evidence based research reveals that patients who commence treatment early after initial diagnosis have better treatment success rates. Chen *et al.* (2018) reported that treatment commenced within two months after performing drug sensitivity testing and empiric treatment were significantly associated with favorable outcomes. An additional benefit is empirical data regarding the operational and acceptability aspects of introducing new diagnostic TB algorithms in practice. This will ultimately improve the utility of Xpert and the future implementation of TB diagnostic assays and technologies currently under different phases of clinical trials.

The anticipation of improved TB treatment outcome after the introduction of novel diagnostic tests like Xpert had been met with different results in different settings. In some settings, Xpert assay resulted in a significant increased proportion of TB patients commencing treatment who had laboratory confirmed diagnosis (Munyoteta, 2015). In other settings, Xpert reduced time to TB treatment (Cox, 2014) and improved case detection in early programmatic implementation in nine of the TB REACH countries (Creswell, 2014). However, in another study, improved diagnosis did not translate to increased number of patients starting anti-TB treatment (Muyoteta, 2015). Challenges identified were stock outs, erratic and delayed result reporting after diagnosis (Cohen, 2014) as well as high equipment failure rates (Creswell, 2014). These factors point towards health systems failing to support novel otherwise cost effective diagnostic tools. Continuous training and development of staff, investments in supplies and infrastructure have been noted to be key for success (Creswell, 2014).

The aim of this study was to determine the Xpert diagnostic and TB treatment initiation delays in Namibia. This was done by calculating the Xpert assay pre-diagnostic and turnaround median time at NIP. Thereafter, the actual median time TB patients commence treatment post Xpert assay diagnosis was established among patients at Katutura TB clinic. The use of Xpert itself is one of the most important tenets within a cascade of activities that must be successful to ensure that TB patients receive appropriate diagnosis, timely and successful treatment**.** NIP render decentralized Xpert testing services in 22 of its 40 laboratories located country wide in public health care centers (MoHSS, 2017). The current study utilized laboratory information systems (LIS) generated turnaround times (TAT) for Xpert assay. The analytical TAT for laboratories is an indicator of their effectiveness and can be used as a quality indicator for laboratory medicine and associated health care services.

METHODS

Study design

This was a retrospective descriptive cross-sectional study that calculated Xpert pre-diagnosis, diagnosis delays and time to treatment post diagnosis.

Study setting and population

The study was conducted at Katutura Intermediate Hospital TB Clinic and NIP using a population comprised of RR-TB and non RR-TB patients. Katutura Intermediate State Hospital is one of two state referral hospitals in the Windhoek area of the Khomas Region. Being an intermediate hospital, it receives RR-TB and complicated non RR-TB referrals from district hospitals. This state hospital also provides secondary and tertiary health care services. NIP is a state-owned commercial entity that provides medical laboratory services in public health facilities in Namibia. Since 2017, this institute utilizes Xpert® MTB/RIF assay (Cepheid, Sunnyvale, CA, USA) for TB diagnosis. All the patients in this study were consecutively recruited from the TB clinic. All the patients were drawn from 7 out of the 14 regions in Namibia. Initial Xpert diagnosis was done at Windhoek Central Hospital, NIP TB Reference Laboratory and peripheral laboratories in these 7 regions. RR-TB patients were admitted in male and female TB isolation wards at the TB clinic whereas drug susceptible TB patients were confined in the TB general wards. Sample size was calculated using G*Power 3.1 software at medium effect size 0.20, margin of error of 0.05 and a two sided 95% confidence intervals (CI). The minimum sample size required for the study was 65 participants. The study enrolled 72 participants consisting of 25 RR-TB and 47 non RR-TB patients who were 18 years old and above.

Study procedures

Data was collected from patients' records that were retrieved from Medical Information Technology (Meditech) at Windhoek Central Hospital, NIP TB Reference Laboratory from 1 July 2018 to 31 March 2019. The study excluded patients from private hospitals and clinics. Identifiers of eligible patients were obtained from clinical records and were used to extract the required information. Date of sample collection, its reception at NIP, testing and the actual date of TB results verification was extracted. Time (days) from diagnosis to treatment initiation was obtained from treatment registers and medical record reviews. Time in days taken at each of these steps per patient was calculated.

Statistical analysis

Delays were measured using time differences (days) between several steps within the cascade of patient care from contact with clinician to initiation of treatment as follows:

(i) First consultation with a clinician to sample collection and transport to the NIP laboratories (Pre-diagnosis/analytical delay).
(ii) Sample reception to result reporting (diagnostic/analytical delay).
(iii) TB diagnosis to treatment commencement (treatment initiation delay) and
(iv) First consultation to treatment commencement (health system delay).

Data from Meditech was coded and double entered into Microsoft Excel (2015) spreadsheet. A double entry template was utilized and data was validated through a series of logical checks. This data was cleaned for errors and analyzed using Stats statistical software version 12 (StataCorp LP, TX, USA). Data was summarized as median and interquartile range for continuous variables such as pre-diagnostic median time, Xpert TAT and treatment initiation delays. Health system delay comprised pre-diagnostic delay, diagnostic delay and treatment initiation delay.

RESULTS

Table 1 Socio-demographic and clinical characteristics of RR-TB and non-RR-TB drug patients at Katutura Intermediate Hospital (Total n=72).

Characteristic	N	%
RR-TB	25	65.28
Non RR-TB	47	34.72
Gender		
Male	39	54.17
Female	33	45.83
Age (years)	Mean=34.9722	SD=9.3823
Annual income (N$, 000)		
≤ 20	55	76.39
>20	17	23.61
Marital status		
Married	13	18.06
Single	50	69.44
Divorced	2	2.78
Widowed	4	5.56
Co- Habiting	3	4.17
Education		
No education	10	13.89
Primary	32	44.44
Secondary	22	30.56
More than Secondary	8	11.11
Employment status		
Formal	7	9.72
Informal	20	27.78
Unemployed	45	62.50
HIV status		
Positive	39	54.17
Negative	31	43.06
Unknown	2	2.78
Residence		
Semi-Urban	39	54.17
Rural	31	43.06
Urban	2	2.78

The study enrolled an almost equal number of males (54.2%) and females (45.8%) whose mean age was 35 years and most (76.4%) of the respondents had an annual income of less than N$ 20 000 with 62.5% being unemployed. More than 2 out of 3 (69.4%) of the participants were single and were staying with household TB patients. About half (54.2%) of the participants were HIV positive and almost two thirds were staying in urban and semi-urban residential areas.

Table 2 Health system delay among the RR-TB and non RR-TB patients of Katutura Intermediate Hospital.

	Median		IQR***	
	RR-TB	**Non RR-TB**	**RR-TB**	**Non RR-TB**
Health System Delay (days)	21	12	2-32	1-12
Pre-diagnostic delay (days)	7.5	5	0-14	1-8
Diagnostic delay (days)	1	1	0-3	0-3
Treatment initiation delay (days)	10	3	1-32	0-12

Health system delay includes pre-diagnostic delay, diagnostic delay and treatment initiation delay.

Diagnostic delay relates to the patients who had Xpert rapid test
***IQR: Inter-quartile range.

Median health system delay was 21 days for RR-TB patients and 12 days for non RR-TB patients.

DISCUSSION

Pre-diagnostic median time

The study revealed that it took seven and a half days for the sample to arrive in NIP TB laboratory for testing. Unlike other studies (Rifat *et al.*, 2015; Hoa *et al*., 2014; Hossain *et al*., 2015) on TB treatment initiation delays, this study evaluated pre-diagnostic delays after sample collection and its reception in the TB laboratory. Jacobson *et al.* (2013) reported that pre-diagnosis delays can be traceable to operational issues like sample delays in collection, transportation, inadequate and incomplete information on laboratory request forms and storage. In Namibia, the NTLP recommends collection and examination of at least two specimens per patient if the Xpert result is positive and rifampicin resistance is detected. One sample is for Xpert assay and the other sample is send to NIP TB Reference Laboratory in Windhoek for LPA and conventional culture. Thus, pre-diagnostic delays are encountered more in RR-TB patients compared to drug susceptible TB patients during the collection. However, the data regarding the impact of sputum quality on TB diagnosis is limited and heterogenous. Poor sample collection techniques and inefficient transport systems have been reported to increase treatment initiation delays and patient attrition (Nkengasong *et al*., 2010). Thus, improving specimen transport and specimen referral systems is crucial in averting pre-analytical diagnosis delays in public health laboratories.

In Uganda, a pilot project on early infant diagnosis specimen transportation network (Borchert *et al*., 2014) reported an increased quality of sample transport and speed to the central reference public health laboratory. Similarly, in Namibia, the roll-out of the Xpert assay to public health facilities with HIV programs provides a crucial opportunity for multi-disease Xpert platform specimen transport and referral systems. This may include assays like HIV resistance testing, viral load, CD4 count enumeration as well as early infant diagnosis. These systems can be integrated to ensure rapid transport of various samples to the laboratories for testing.

Analytical diagnostic delay time

The study illustrated that it takes a day for Xpert RR-TB and non RR-TB diagnosis since the roll-out of this assay in 2017. This demonstrates that the use of Xpert contributes to reduced delays in RR-TB diagnosis and hence time to treatment initiation. Consequently, Xpert is addressing some of the challenges in the diagnosis reported in Namibia TB drug resistance survey in 2016.

Xpert roll-out requires massive investments in labor. Namibia University of Science and Technology (NUST) introduced a degree in Medical Laboratory Sciences. Most of the graduates received their clinical attachment at NIP including rotations in the TB laboratory. NIP is also the biggest employer for laboratory professionals in the country. The institute also receives support from NGOs and donors including USAID, CDC, I-TECH Namibia and Global Fund to improve the testing quality. There is need to extend Xpert training and interpretation of results to other health workers like clinicians, pharmacists and nurses.

NIP also benefits from its participation in regional TB programs like the East, Central and Southern African (ECSA) Health Initiative. Through its participation in continuous quality improvement programs for TB diagnosis, reliable and accurate results are generated to ensure customer satisfaction. Although the NIP TB laboratory is not yet accredited to any professional body, it receives assistance from the USA CDC through the provision of Dried-tube specimen-based proficiency panels (Klein *et al*., 2015). One major challenge is lack of Xpert extensive external quality assessment programme at NIP. However, the NTLP run comprehensive national external quality assessment programs for sputum smear microscopy. These include on-site auditing visits, panel testing, feedback and corrective action (MoHSS, 2011). These programs are very crucial and hence roll-out of the Xpert assays in Namibia can correlate with smear microscopy networks to enhance quality laboratory management systems.

Accuracy and reliability of Xpert assays should be integrated with systems for HIV testing. In South Africa, Scott *et al.* (2014) report peripheral monitoring of HIV viral load testing, Xpert assays and CD4 count assays. Continuous monitoring and evaluation of HIV programs can offer a comprehensive model to sustain quality

assurance for the Xpert assay. However, the assay implementation is very intensive as the cartridges, continuous electricity supply and calibrators are very expensive. Cox *et al*. (2018) examined the drug resistant gap and treatment initiation delays after Xpert implementation in South Africa. The median laboratory time was one day whilst the median time to treatment was 19 days. The study concluded that treatment gaps exist but less than those reported within routine data. However, many patients faced long delays to treatment. The study established that the Xpert assay has improved time to second line treatment initiation but the centralized treatment program was a barrier to treatment accessibility in many health care settings. In the current study, the median time for RR-TB diagnosis is comparable to a study done in South Africa. Another study by Hossain *et al*. (2015) presented the median time for diagnosis as four days and median time for treatment initiation as five days.

Treatment initiation delay time

It took ten days for RR-TB patients to initiate second line TB treatment after Xpert diagnosis. Overall it took 21 days for a RR-TB patient to initiate treatment after sample collection as compared to 12 days for drug susceptible patients. Treatment initiation delays could be attributable to increased number of patients on the waiting list for treatment initiation and admissions at Katutura specialized TB clinic. NLTP (2015-2016) annual report shows a 27.9% increase in MDR-TB cases enrolled for treatment between 2014 and 2015. During the same period (2015-2016) community based tuberculosis care (CBTBC) providers registered 79% patients through case detection (MoHSS, 2017). In South Africa, Padayatchi *et al*. (2014) concluded that although the Xpert roll-out reduced time to MDR-TB treatment initiation, increased number of patients on the waiting list for treatment commencement occurred due to higher case detection. Thus, adequate planning, resource mobilization and allocation are crucial to MDR-TB management at specialized facilities. Other factors to monitor and evaluate are drug resistant TB supply chain management and work load of specialized health care workers. In Namibia, there are less than ten TB consultant pulmonologists to manage DR-TB cases in the public health facilities and the capacity to provide quality RR-TB management and scale-up of its treatment is limited. Task shifting management can be a viable option. Well *et al.* (2013) aver that future phenotypic and genotypic DST assays to new anti-TB drugs might gain from implementation of Xpert assay.

In the current study among 25 RR-TB cases, 2 (8%) had Xpert-LPA discordant results, 4 (16%) had genotypic (Xpert and LPA)-phenotypic discordant results and 2 (8%) had phenotypic-whole genomic sequencing discrepant results. However, the level of training which clinicians received to interpret genotypic and phenotypic results is unknown yet this training offers an additional benefit to refresh them on TB management and diagnosis. This could have contributed to delays in switching to appropriate second line regimens, as patients remained on failing regimens. Development of XDR is inevitable due to delayed switching to appropriate second line and other anti-TB regimes. Future studies should characterize the impact of discordant results on treatment outcomes, cost and health system.

In Namibia, financing from domestic sources and donors is pooled through central budget support at central or district level. TB and leprosy intervention activities are funded by on-budget contributions channeled through the NTLP and complementary funding support from United States Centers for Diseases Control and Prevention (CDC), United Stated Agency for International Development (USAID) and Global fund in a 60:40% ratio respectively (MoHSS, 2017). In a recent survey of 22 high TB burden nations, Scott and colleagues (2014) established that although 86% of these countries had Xpert algorithm, most implementation was donor-supported and was not considered sustainable in the long run. Thus, it is crucial to incorporate evidence-based recommendation into clinical and laboratory guidelines and policies within the NTLP and HIV programme.

According to the National Planning Commission report (2018), Namibian domestic economy registered a growth of just above 1.0% in 2016 whilst in 2017 the economy was estimated to have declined by 0.4%. The end of I-TECH Namibia's support as the biggest in-service training provider to MoHSS adversely affected NTLP's TB training role including Programmatic Management of Drug-resistant TB (PMDT). A decrease in overall Namibian economic growth and unsustainable donor funding could have had an impact on anti-TB drugs supply chain, training of staff and supervision. These are key determinants to RR-TB treatment initiation delays. Quality assurance and supervision are required from sample collection to treatment initiation, so is rigorous monitoring and evaluation of the whole treatment success cascade.

Evans *et al*. (2018) determined the proportion of people diagnosed with RR-TB who initiated treatment in Johannesburg after the introduction of decentralized RR-TB care in 2011. The median time from sputum collection to treatment initiation was 33 days. In South Africa, it can be observed that despite decentralized RR-TB treatment sites in most provinces, some patients fail to initiate appropriate treatment. Thus, decentralized treatment at these sites alone is necessary but insufficient. Difficulty to take conventional MDR-TB treatment has a myriad of side effects including renal and liver damage, permanent deafness, psychosis and nausea. Falzon *et al*. (2013) argue that MDR-TB treatment may require over 14 000 tablets and injections for up to 2 year.

Before being enrolled for MDR-TB treatment, Naidoo *et al.* (2014) proclaim that baseline clinical tests like liver function tests (LFT), full blood count (FBC), kidney function tests, audiometry, xray, thyroid function tests, random blood sugar assessment is a necessity for every patient. In Namibia, the National Guidelines for the Management of TB states that these tests are part of minimum requirement for treatment initiation. In addition, the RR-TB patients also undergo "clinical assessment and weight measurements, baseline sputum smear microscopy, culture/DST, CD4 count, urine pregnancy (if applicable), HIV counseling and testing (and assessment for HAART if positive, if already on HAART Viral load to be considered), assessment by a social worker and lastly health education and signing of consent form" (MoHSS, 2011). This might explain the observed treatment initiation delays after diagnosis. Additionally, unlike rifampicin sensitive TB patients all MDR-TB treatment requires hospitalization at specialized centers which involves referrals. MDR-TB patients therefore require adequate preparation before admission in TB isolation wards for periods up to more than 24 months. Namibia has critical shortages of specialist pulmonologists in public hospitals to monitor prognosis to treatment. Thus, arrangements have to be made prior to admissions of MDR-TB patients from peripheral health care centers.

STRENGTH AND LIMITATIONS

This study recruited patients who were already on RR-TB and non RR-TB treatment. There was paucity of information on patients who did not start treatment after diagnosis. Lastly, the study recruited only patients who used the Xpert assay at NIP and those with incomplete medical records (lack of information) and whose diagnosis was done at other laboratories were excluded. However, the use of the LIS was crucial in determining the diagnostic and pre-diagnostic delays.

CONCLUSION

The median time from sample collection and Xpert assay testing is very long in Namibia. There is need to integrate the Xpert implementation and strengthen it with other systems and health care programs. The current study illustrated that the Xpert assay has improved time for rapid RR-TB diagnosis and median time to second line treatment initiation since its roll-out in 2017. Xpert assay improves patient outcomes if maximally placed and implemented within the context of NTLP. Roll-out in resource constrained sites offers an opportunity to address current barriers to optimize success along with HIV viral load assays, CD4/CD8 testing and early infant diagnosis. Xpert assay also provide a strong platform through which future TB diagnosis assays will be leveraged and implemented. Thus, the Xpert benefits can also harness and improve system-wide capacity for TB diagnosis and treatment as well as attaining global "End TB Strategy" goals and enhancing global public health. Another focus area is to strengthen the quality assurance, robust monitoring and evaluation (M&E) at all levels of Xpert implementation.

Treatment initiation to appropriate second line drugs are still long for many patients and may be ascribed to poor interpretation of discordant results, increased number of RR-TB patient for treatment commencement, unnecessary referrals due to shortages of pulmonologists, baseline investigations and outdated guidelines and policies. Consequently, this calls for refresher courses for clinicians, strategic planning, resource mobilization and continuous coordination between TB and HIV Programs. There is need to strengthen TB whole genomic sequencing (WGS) assays processing for patients with discordant results with strategic partners like the University of Namibia, School of Medicine and efficient coordination with international partners, stakeholders, facilities and laboratories. Lastly, the actual treatment gap among RR-TB patients and risk factors for delayed treatment need to be explored.

ABBREVIATIONS

CDC	:	Disease Control and Prevention
DOTS	:	Directly Observed Treatment – Short Course (WHO strategy)
DR-TB	:	Drug Resistant Tuberculosis
DST	:	Drug Sensitivity Testing
ECSA	:	East Central and Southern Africa
HAART	:	Highly Activated Anti-Retroviral Treatment
HIV	:	Human Immunodeficiency Virus
I-TECH	:	International Training and Education Center for Health
KNCV	:	Koninklijke Nederlandse Centrale Vereniging (Royal Dutch Tuberculosis Association)
LPA	:	Line Probe Assay
M&E	:	Monitoring and Evaluation
MDR-TB	:	Multi-Drug-Resistant Tuberculosis
MoHSS	:	Ministry of Health and Social Services
MSH	:	Management Sciences for Health
NGO	:	Non-Governmental Organization
NIP	:	Namibia Institute of Pathology
NPC	:	National Planning Commission
NTLP	:	National Tuberculosis and Leprosy Programme
NUST	:	Namibia University of Science and Technology
PEPFAR	:	President's Emergency Plan for AIDS Relief
RR-TB	:	Rifampicin Resistant Tuberculosis
USAID	:	The United States Agency for International Development
WGS	:	Whole Genomic Sequencing
WHO	:	World Health Organization
XDR	:	Extremely Drug Resistant Tuberculosis

Ethical approval and consent to participate

Ethical approval for the study was granted by the Information Management and Research Unit in the Ministry of Health and Social Services, Namibia (Ref:17/3/3 FFC). Permission to conduct the study was given by the management of Katutura Intermediate Hospital and NIP. Verbal consent was sought from each patient after fully informing them about their

participation before collecting data. Measures were taken to protect the patients' identity during the data compilation, storage and analysis. Once the data was collected, it was kept secured and was analyzed as aggregate.

Consent for publication
Not applicable.

Availability of data and material
All the datasets analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests
The authors declared that they have no competing interests.

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Author's contributions
FFC: Designed, collected and analyzed the data
TM: Discussion of results
LND, PTG: Data analysis
MM, AC, MM and GAM, HA: Contributed to the writing of the manuscript
MMS: Proof reading and provided critical feedback
All the authors read and approved the final manuscript
Competing Interests
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