Local Production of a Cas12-based typhoid diagnostic in Cameroon via a novel academic-community partnership

Stakeholder Engagement Report

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PROJECT PARTNERS

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EXECUTIVE SUMMARY

Enteric fever (typhoid and paratyphoid fever) is a systemic infection caused by the gram-negative bacteria *Salmonella enterica* serovar Typhi (S. Typhi) and Paratyphi A, B &C (S. Paratyphi) which are highly contagious and rapidly spread through ingestion of contaminated water and food in poor sanitary conditions. The disease causes approximately 17.8 million cases and 75,000–208,000 deaths worldwide each year (Antillón et al., 2017), predominantly in those under five years of age (Arora et al., 2019). In enteric fever is widely recognized as a national public health concern and the Global Health Data Exchange data estimates there were 45,000 cases and 580 deaths in 2016 (*Global Burden of Disease Study, 2017*). Enteric fever is treatable with antibiotics but its signs and symptoms are non-specific and overlap with malaria and other febrile illness which makes the prognosis presumptive.

There is a clear need for rapid and accurate diagnosis, which the CRISPR-TyphoidDx project is addressing via development of a low-cost and highly sensitive and specific molecular test. The design of the final diagnostic must be led by and address the needs of Cameroonian clinicians, patients and other stakeholders. Therefore, stakeholder engagement was undertaken through a series of interviews and questionnaires to understand the current state of typhoid diagnostics in Cameroon, perceived limitations and possible solutions from the perspective of various stakeholders. This data will allow us to make relevant decisions on the development of CRISPR-TyphoidDx and the pathway to adoption and impact of a molecular diagnostic for typhoid fever.

Several conclusions can be drawn from the stakeholder engagement. These include:

- The current diagnostic methods and diagnostic tools for typhoid diagnoses are severely limited with regards to efficacy, efficiency and affordability.
- These limitations have a considerable impact on the health care delivery and proper diagnosis of typhoid fever.
- There is a need for affordable novel diagnostic methods with greater capabilities as involves the diagnosis of typhoid fever.
- Adoption of molecular diagnostics in local health centres shall require strategic assistance.

The implications for the design of the CRISPR-TyphoidDx diagnostic are that great care needs to be paid to ease of use and cost while not compromising on sensitivity and specificity. However, the benchmark provided by existing tests is quite low and significant improvements over the current standard are very achievable.

Results from NGOs, infectious disease researchers and public health officials are pending due to the challenges of organising interviews with these groups during a public health emergency.

1. INTRODUCTION

1.1 The global health challenge of enteric fever

Enteric fever (typhoid and paratyphoid fever) is a systemic infection caused by the gram-negative bacteria *Salmonella enterica* serovar Typhi (S. Typhi) and Paratyphi A, B &C (S. Paratyphi) which are highly contagious and rapidly spread through ingestion of contaminated water and food in poor sanitary conditions. The disease causes approximately 17.8 million cases and 75,000–208,000 deaths worldwide each year (Antillón et al., 2017), predominantly in those under five years of age (Arora et al., 2019) and in South and South-East Asia and sub-Saharan Africa (WHO). Enteric fever is treatable with antibiotics but its clinical management presents two challenges:

1. the clinical signs and symptoms of typhoid fever are non-specific and overlap with malaria and other febrile illness which makes the prognosis presumptive.

2. the diagnostic tests take up to seven days to report, which has led to the overuse of antibiotics leading to antimicrobial resistance (AMR) and multidrug resistance (MDR) in Africa and elsewhere (Park et al., 2018).

There is therefore a need for rapid and accurate diagnosis of typhoid fever. In low-resource settings, serological tests are most commonly used. Infections can be detected in blood or stool samples but blood is preferred for differential diagnosis of active infections because there can be asymptomatic faecal shedding following the infection which may coincide with a different symptomatic illness, giving an incorrect diagnosis (Vaccine Preventable Diseases Surveillance Standards, 2018). The Widal test is the oldest and most popular method that tests antibodies against the O and H antigen of S. Typhi but it has to be an due to (a) cross-reactivity with antibody from many other infections (b) establishing a baseline in the population where the infection is endemic and actively vaccinated (Olopoenia & King, 2000).

The current commercially available rapid enteric fever diagnostics used globally detect immunoglobulin antibodies IgG or IgM. However, serological testing has been demonstrated to have poor sensitivity and inadequate specificity (Wijedoru et al., 2017). Nucleic acid tests (NATs) have higher sensitivity and specificity but are not typically in use in typhoid-endemic countries due to the complexity of the test design, cost and requirement for laboratory facilities compared to serological tests. There have been numerous scientific publications demonstrating S. Typhi and S. Paratyphi detection by PCR , real-time PCR and loop mediated isothermal amplification (LAMP) (e.g. Kaur et al., 2018; Fan et al., 2015; Nga et al., 2010; Tennant et al., 2015; Frickmann et al., 2019; Francois et al., 2011) but none are currently in wide use.

1.2 The CRISPR-TyphoidDx project

The CRISPR-TyphoidDx project is a UK-Cameroon collaboration focused on addressing enteric fever diagnostic needs in Cameroon, where the disease is widely recognized as a national public health

concern. The Global Health Data Exchange data estimates there were 45,000 cases and 580 deaths in 2016 (Global Burden of Disease Study, 2017). As in many other countries, almost none of the Cameroonian population are vaccinated against typhoid and the drugs of choice for the treatment of typhoid fever are fluoroquinolones or third generation cephalosporins (Nkemngu et al., 2005), making AMR and MDR a major concern. While outbreaks of AMR typhoid fever have been reported in 15 African countries since 1950, the reports of those outbreaks in Cameroon are limited due to limitations in facilities available for testing.

We therefore focused on developing a rapid DNA-based molecular test for S. Typhi and S. Paratyphi that would address the needs of Cameroonian clinicians, patients and other stakeholders and that could be adapted for rapid genotype based testing of AMR to inform clinical management and allow data collection for AMR surveillance.

2. METHODOLOGY

Stakeholder engagement was undertaken through a series of semi-structured interviews and structured questionnaires to understand the current state of typhoid diagnostics in Cameroon, perceived limitations and possible solutions from the perspective of various stakeholders.

2.1 Survey design

The survey was designed to collect data that would help us to make relevant decisions on the development of CRISPR-TyphoidDx and the pathway to adoption and impact of a molecular diagnostic for typhoid fever.

This required further understanding of the burden of typhoid fever in Cameroon from a range of perspectives and gaining insight into existing diagnosis and treatment. From the different stakeholders, we sought insight on:

- Commonly used diagnostic methods for typhoid in Cameroon, their limitations and impact on health care delivery.
- The current state of typhoid antibiotic resistance in Cameroon.
- What pathways to impact within the local health system could enable effective and timely health system planning and delivery of a novel diagnostic.
- Opportunities for and challenges to adoption and use of molecular diagnostics within local hospitals.
- The local policy environment that may hinder or enable adoption of molecular testing in public and private diagnostic laboratories through capacity building and other means.

The questions were tailored to each stakeholder to ensure they were relevant and comprehensible based on their expertise and experience. A pilot study was undertaken with close contacts before the surveys were deployed and they were also translated into both English and French as surveys were conducted in different parts of Cameroon where different languages dominate.

Copies of the survey can be found in Appendix 1.

2.2 Stakeholder demographics

We targeted the following stakeholders with expertise and active experience of the typhoid challenge in Cameroon. In some cases we were not able to arrange an interview during the time period allocated or obtain a completed report:

- Medical doctors from both public and private sectors (9 individuals surveyed)
- Medical laboratory technicians (7 individuals surveyed)
- Scientific researchers working on typhoid fever (5 individuals surveyed)
- NGOs (no respondents)
- Public health officials (no respondents)

Stakeholders were sampled on an ad hoc basis in this first round of interviews, through contacts and institutions known to the collaborating researchers.

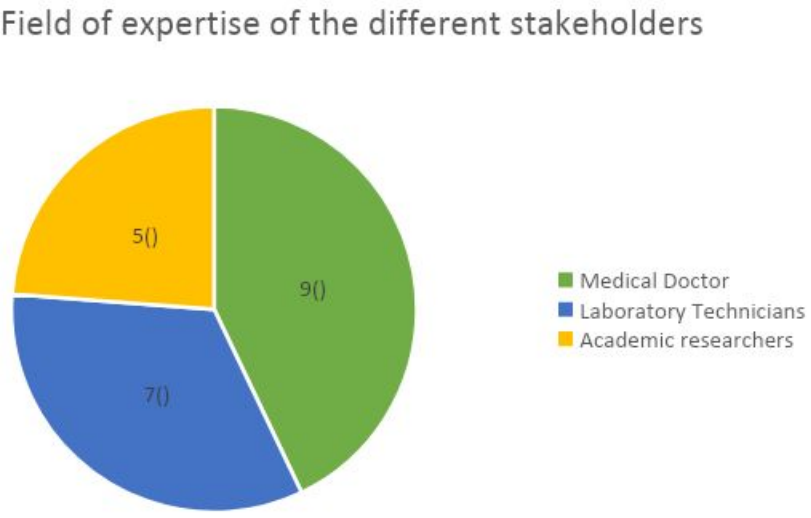

Figure 1: Stakeholders included personnel from the health sector and academic researchers.

2.3 Ethical Approval

Ethical approval for the study was obtained from the Department of Engineering Ethical Review Board at the University of Cambridge and the University of Buea. Each survey respondent was

clearly informed about the purpose of the study and their roles as stakeholders before informed consent was obtained for use of the data provided. Copies of participant information and consent forms can be found in Appendix 1.

3. KEY FINDINGS

3.1 Typhoid diagnostic challenge in Cameroon

Accurate diagnosis of typhoid fever is highly dependent on laboratory investigation due to the nonspecific signs and symptoms presented by the disease. In Cameroon diagnostic efficacy is reportedly limited due to four main challenges; specificity, sensitivity, efficiency and affordability of existing tests. We therefore questioned medical doctors and medical laboratory technicians about their experiences with existing tests.

I. **Specificity:** according to medical laboratory technicians from different hospitals and private laboratories, serological tests (Widal test, Typhidot rapid diagnostic test etc.) are most often used for diagnosis of typhoid fever. We asked two questions in order to understand what the respondents would consider the standard test for typhoid fever and what they did in practice, in case those two answers differed. 3 out of 7 laboratory technicians considered serological tests to be the standard diagnostic, whereas WHO recommends culture-based methods.

   This is due to the low specificity of serological tests and particularly the Widal test, which mixes blood samples from patients with a suspension of inactivated S. Typhi. If the patient has antibodies against the bacterial antigens there is an agglutination reaction but this is prone to cross-reactivity with other Salmonella species. Serological tests are also unable to differentiate ongoing or recent illness from past infections because recovered patients will still have antibodies in their blood. Low specificity was identified by most respondents as a limitation of standard procedures.

"We have an issue because currently, the widely used test which is still not very approved is the Widal test which is not very helpful in diagnosis given that it is a serological test, deals with antibodies and patients who have previously been exposed will be positive and the interpretation at times is subjective."

Among respondents, the "gold standard" of blood culture or stool culture are used to a lesser extent than serological methods, with stool culture being the second most reported

standard test.

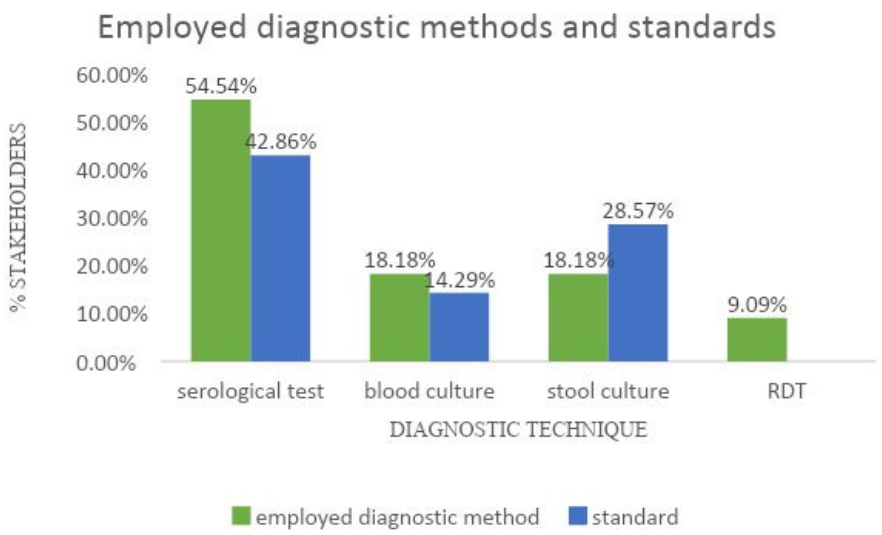

Figure 2: Diagnostic methods reported by seven medical laboratory technicians as the standard for typhoid fever and those that are typically employed in their labs. Most laboratories used at least two methods with one typically considered the standard.

II. **Sensitivity:** Sensitivity issues were mostly associated with stool culture, reported as the second "standard" procedure for the diagnosis of typhoid and also to a lesser extent with blood culture. Isolating the *Salmonella enterica* serovars Typhi and Paratyphi was identified as the main issue and the whole process required experienced personnel for higher chances of isolation. The clinical implications of these were reported to be delays in proper diagnosis and treatment of the patient.

"For most cases, we actually miss isolating the target bacteria because it is very difficult to isolate. Probably because it is always in the midst of bacteria species of the same family that are way more active when it comes to replicating and duplicating themselves in the system and they may not require some special advantages to proliferate so they end up overshadowing Salmonella. ……. The clinical implication is that it actually delays the proper diagnosis of the infection and as such may put the patient in a very risky position."

III. **Efficiency:** Blood culture and stool culture were reported to be time-consuming and cumbersome. Stool culture reportedly takes about 72-96 hours to yield proper results and this eventually leads to delays in diagnosis. The most time-efficient test seemed to be the Widal test, but this advantage is limited due to its low specificity.

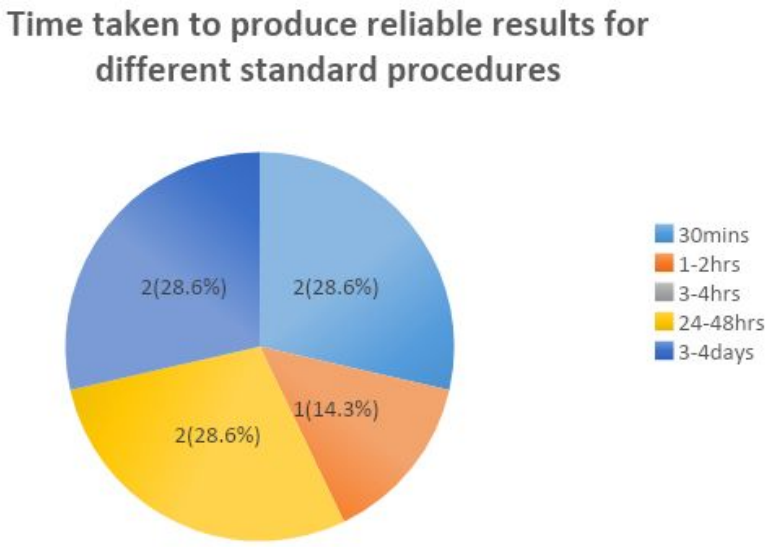

Figure 3: Time taken by different standard procedures to produce reliable results: Serological test (1/2-2hr), culture (24-96hrs).

IV. Affordability: The laboratory investigations to be performed are reportedly decided by the medical doctor. These decisions depend heavily on the cost of the test and the ability of the patient to afford the test. This helps to explain why serological tests are the most popular typhoid diagnostic as they are considerably cheaper than culturing. A stakeholder highlights the importance of this in his statement:

You don't just consider using the gold standard, you have to consider the health economics.....most often the standard which normally should either be the stool culture and so on, which could give us a more concrete diagnosis, but patients may not be able to afford..... We end up having to make the diagnosis without a very concrete confirmatory test.

3.2 The current state of typhoid antibiotic challenge and antibiotic resistance

Fluoroquinolones (88.9%) and Cephalosporin (77.8%) are the most prescribed class of antibiotics reported by stakeholders. The prescription choice is largely influenced by pregnancy or lactating mothers (88.9%) for whom fluoroquinolones may not be safe and by antibiotic susceptibility profile (77.8%). Antibiotic susceptibility is necessary to take into account due to high abuse of antibiotics by patients as attested by a stakeholder:

There is a lot of abuse of antibiotics so when going into the medical history of the patient we want to know from the drug history what kind of antibiotic has often been taken.

…… so we find out that some patients may have abused the use of ciprofloxacin so there is a high probability of resistance in those patients so we try not to prescribe it. …… I would say that we rarely send for resistance test due to affordability

Antibiotic susceptibility testing was reported to be rarely requested by medical doctors due to its cost and so determining antibiotic resistance is largely based on patient history. This explains why 33.3% (3 out of 9) of medical personnel mentioned they couldn't tell definitively how often they encountered patients with resistance to the prescribed antibiotic.

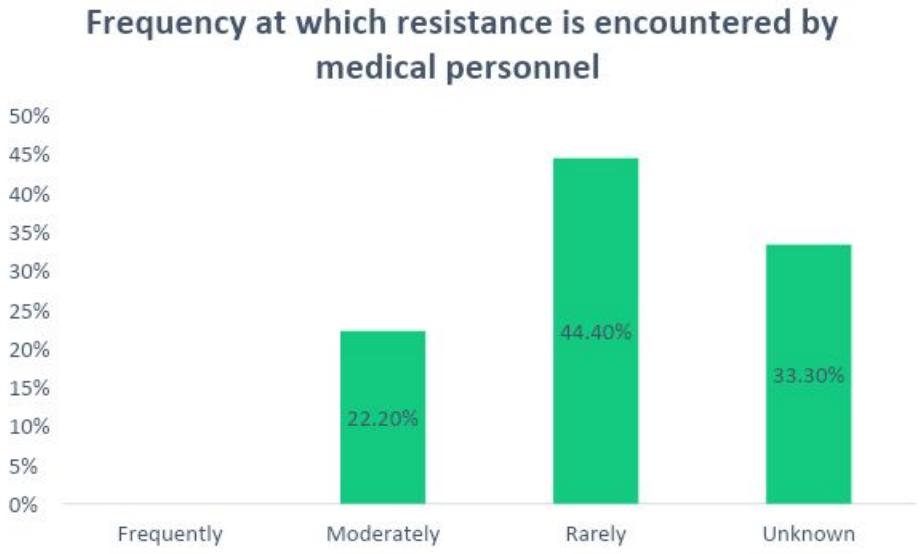

Figure 4: How often resistance was encountered to prescribed antibiotics by different medical personnel. 2 (22.2%) medical doctors reported moderately, 4 (44.4%) doctors reported rarely, and 3 (33.3%) doctors reported unknown.

3.3 Importance and feasibility of typhoid molecular test

It is evident that typhoid diagnosis in the Cameroonian health system suffer severe limitations in both public and private hospitals. The five requirements stated by the stakeholders for an effective diagnostic tool for typhoid were: high specificity and sensitivity, availability and usability, comprehensive in the detection of typhoid fever and antimicrobial resistance, speed and accuracy. The stakeholders agreed that most of these requirements could be fulfilled by a molecular test but the feasibility of employing molecular diagnostic in the local health care centres was questioned due to cost and expertise required to handle molecular techniques.

"Feasibility, [on a scale of a hundred, would be 40% because] it requires some level of expertise, level of keenness..."

"It is not very feasible due to cost"

By mitigating cost, there is general approval that a rapid, specific and sensitive molecular diagnostic test could streamline diagnosis, hasten treatment of patients and reduce the cost of treatment and health care delivery. The additional ability to detect antimicrobial resistance was identified as crucial to the effective and efficient administration of treatment.

" .... that will be very important because we can begin to know what to tailor treatment to because at times you treat the patient and the patient comes back with the same symptoms and you need to be sure if this is a case of antibiotic resistance or a problem of the wrong diagnosis."

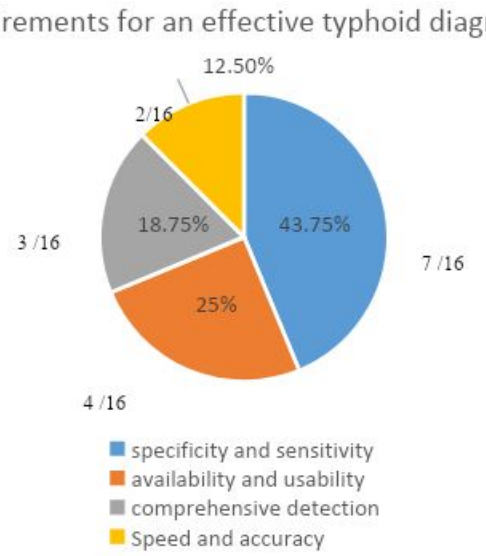

Figure 5: Features for an effective typhoid diagnostic

3.4 Adoption and integration of molecular diagnostic into local health care centres

Possible adoption of the molecular diagnostic test into local health centres will entail the provision of a basic technical platform to ease adoption, availability of the molecular diagnostic, validation by the health authorities, little requirement for expertise in handling the molecular diagnostic, and creation of awareness through workshops and training sessions; as proposed by the stakeholders. No information was obtained on the policy, regulatory and technical support required to introduce new diagnostics into private and public laboratories or on local policies to build the capacity of public and private laboratories. These questions are pending, awaiting a response from public health officials.

4. CONCLUSIONS

The stakeholder engagement granted insight into the state of typhoid and its diagnostic limitations in Cameroon. It also highlighted important issues that could be addressed with the production of a comprehensive, cost-effective typhoid diagnostic.

Several conclusions can be drawn from the stakeholder engagement. These include:

- The current diagnostic methods and diagnostic tools for typhoid diagnoses are severely limited with regards to efficacy, efficiency and affordability.
- These limitations have a considerable impact on the health care delivery and proper diagnosis of typhoid fever.
- There is a need for affordable novel diagnostic methods with greater capabilities as involves the diagnosis of typhoid fever.

- Adoption of molecular diagnostics in local health centres shall require strategic assistance.

The results supported the relevance of our overall aim for the CRISPR-TyphoidDx project:

We aim to develop a proof-of-principle DNA-based typhoid diagnostic using Cas12. The diagnostic tool will be capable of distinguishing S. Typhi from S. Paratyphi, will be produced in Cameroon and will have a reagent cost of < $1 per reaction.

However, they highlighted areas where we need to think hard about design and future directions, in order of priority for survey respondents. The current CRISPR-TyphoidDx project ends at the point where the test is working in the lab with purified DNA samples but we aim to continue beyond this project to further develop the test with the aim of eventually deploying it:

1. **Sensitivity and specificity:** this validates our choice of RPA-Cas12 as these have been shown to be among the most sensitive detection methods for nucleic acids. Bacterial load in acute typhoid is low, the WHO reports an average of < 1 cfu/mL of blood which makes the use of a sensitive technique essential. The low specificity and sensitivity of the current tests that was reported by nearly all respondents shows that creating a test that exceeds the current standard diagnostics is achievable at a technical level but the real challenge will be scaling and deployment.
2. **Availability and usability:** the respondent who rated the likelihood of a molecular diagnostic as 40% feasibility is a timely reminder of the challenges in terms of pathways to impact. They highlighted expertise and keenness as two requirements that may be a barrier, which provides us with targets to overcome with a future test design. Options may include ensuring that the test has a similar workflow to existing diagnostics and that it requires little effort on the part of the medical laboratory technicians. Recently, RPA-Cas12 reactions have been adapted to work on lateral flow strips which are familiar in many diagnostic labs and could provide an opportunity to release the level of expertise required.
3. **Comprehensive detection:** Diagnosis of S.Typhi and S. Paratyphi was highlighted as important but testing for AMRs did not emerge a top priority for most respondents. The public health data indicates that it is a high risk but as most clinicians reported that they rarely encountered it or they did not know if it was present, it is understandable that diagnosis is paramount and that this would be a secondary concern for the survey demographic.
4. **Speed:** this was not a priority for the respondents which means that we can focus future development on affordability and ease of use. This is useful to know as a lot of optimisation goes into increasing the speed of tests, particularly when aiming for very rapid tests with results in 10 min or less. Based on survey responses and the current test landscape, up to two hours would still be an impactful improvement on the several days taken for blood cultures.

The future directions planned for the project include:

1. **Application of Cas12 to other communicable and non-communicable diseases** that are a priority for Cameroon. During the interviews, other priority diseases such as malaria, gastric ulcer due to *Helicobacter pylori*, syphilis, amoebiasis, non-typhoidal infections, and chlamydia were reported as other priorities to benefit from a rapid and cost-effective molecular diagnostic.
2. **Transferring the resulting diagnostic to other parts of Sub-Saharan Africa** and even further afield to reduce the 75,000–208,000 annual deaths worldwide from enteric fever (Antillón et al., 2017). We based this aspiration on the assumption that if we are able to develop a test that is successful in Cameroon, it should be feasible with adaptation where health systems are similar. The stakeholder engagement exercise did not query this point but nothing that we found out about the Cameroonian health system suggests that it is atypical or that what works here would be particular and not transferable to other settings.
3. **Expansion to multiplex detection of MDR genotypes** based on the findings of our feasibility study: as described above, AMR did not emerge strongly as a priority for stakeholders and so this would be the lowest priority of the three future directions for now although it is very interesting from an academic research perspective and would also require a long development time. We will therefore keep it on the table as a priority for a future phase of the project.

ACKNOWLEDGEMENTS

We are grateful to the stakeholders for their time and participation even during a global health crisis, which demonstrates the importance of addressing the challenge of typhoid diagnosis.

Appendix I: Questionnaire

Local production of a Cas12-based typhoid diagnostic in Cameroon through a novel academic-community partnership

Stakeholder Engagement

Project Description

This project aims to develop a low-cost DNA-based diagnostic tool for *Salmonella* Typhi and Paratyphi using Cas12, a revolutionary and versatile platform for sensitive molecular diagnostics. Its principle is based on an enzyme guided by RNA to detect very specific DNA sequences on the Salmonella species genome. Upon recognition, Cas12 cleaves a reporter DNA, releasing a fluorescent read-out (Chen *et al.,* 2018). This technology improves sensitivity to attomolar quantities of DNA and offers the ability to design multiplex assays (Gootenberg *et al.,* 2018) in order to detect more than one specific DNA sequence. This implies that genes associated with resistance can be detected e.g. MDR mutations without the need to sequence the bacteria's genome.

Your engagement as a stakeholder will give Important insight into:

- The current state of typhoid antibiotic challenge in Cameroon
- Commonly used diagnostic methods in Cameroon, their limitations and impact on health care delivery.
- What pathways to impact within the local health system that will enable effective and timely health system planning and thus health care delivery.
- Possible adoption and use of molecular diagnostics within local hospitals.
- Local policies that enable capacity building in public and private diagnostic laboratories.

CONSENT FORM

Your participation in the survey is entirely voluntary. You are not under any obligation to participate, and you have the right to refuse this invitation. You are not entitled to any financial benefits for participating in this study, but your participation will contribute to the understanding of the current state of typhoid, and it's management in Cameroon.

There is no foreseeable risk involved in participating in this study. All information related to your participation will be kept confidential and will not be revealed to anyone. Your identity will not be revealed in any reports or publications resulting from the study.

Please confirm the following to consent to participate in the project "Local production of a Cas12-based typhoid diagnostic in Cameroon through a novel academic-community partnership;

- I have read and understood the project information sheet
- I agree to take part in the project and I understand that my taking part is voluntary; I can withdraw from the study at any time.
- I understand that my words and responses may be quoted anonymously in publications, reports, web pages, and other research outputs, stored in a repository so they may be used for future research and learning.
- I agree to joint copyright of my survey responses with Dr Jenny Molloy and/or Dr Tobias Apinjoh, or members of the research team, to enable them to use the information as outlined.

I AGREE: **I DISAGREE:**

Questions: (Laboratory technicians, NGO's)

Where applicable please answer the following questions by either ticking the right answers or writing the letters to the right answers in the space provided. More than one answer can be chosen.

1. What are the requirements for diagnosing typhoid?

   A. Lab investigations,

   B. Patient history,

C. Clinical presentation (signs and symptoms)

D. Stool, urine or blood

E. other

2. What diagnostic methods do you use for diagnosing typhoid?

   A. Serological test (Widal, Typhidot, TUBEX-TF) **B.** Blood culture. **C.** Microscopy **D**. Polymerase chain reaction **E**. Other

3. Which of these diagnostic procedures would you consider the standard in your lab?

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4. How long does this procedure take to produce reliable results?

A. 30 mins **B.** 1-2 hrs **C**. 3-4hrs **D**. 24-48hrs **E.** Other

5. How specific is the afore-mentioned procedure in detecting Typhoid (False negatives)?

A. Very specific (no false negatives) **B.** Partially specific (few false negatives) **C.** Non-specific **D.** undefined **E.** Other

6. What limitations do you encounter with these diagnostic procedures?

A. Cross-reactivity with other salmonella species

B. Non-specificity (results are influenced by multiple factors)

C. Inability to distinguish current and previous infection

D. Cumbersome and Time-consuming

E. Costly

F. Requires specialised personnel

7. What is the impact of these limitations on proper diagnosis and effective health care delivery as a whole?

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8. What Molecular diagnostic techniques do you know that are currently in use for the diagnosis of typhoid?

A. PCR **B.** Nested PCR **C.** Real-time PCR **D.** Multiplex PCR **E.** Blood culture- PCR **F.** Other

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9. What limitation do you experience with this technique?

A. Low Sensitivity **B**. Costly **C**. Low Specificity **D.** Cumbersome **E.** Requires specialised personnel **F.** We do not use molecular diagnostics for the diagnosis of typhoid **G**. Other

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10. What measures can be taken to ease the adoption of molecular diagnostic techniques in local health care centres?

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11. What pathways within the local health care system can be impacted to improve diagnostic capabilities of diagnostic laboratories?

12. What other priority diseases can benefit from rapid and cost-effective molecular diagnostic tools?

EXTRA INFORMATION

Questions: (Medical doctors)

Where applicable please answer the following questions by either ticking the right answers or writing the letters to the right answers in the space provided. More than one answer can be chosen.

1. What are the requirements for diagnosing typhoid?

2. What can be done to improve diagnosis of typhoid?

3. How many patients do you encounter in a day showing clinical symptoms common to typhoid?

   A.1-4 **B**. 5-7 **C**. 8-10 **D.** 11 **E**. Unknown

4. What class of antibiotics do you commonly prescribe for typhoid fever?

   A. Fluoroquinolones (ciprofloxacin, ofloxacin, ornidazole)

   B. Cephalosporins (Ceftriaxone,Cefixime)

   C. Nitro-imidazole (Tinidazole)

   D. Tetracycline

   E. Ampicillin

   F. Azithromycin

   G. Chloramphenicol

   Others

5. What factors determine the antibiotic to be prescribed? **A**. Antibiotic susceptibility profile **B**. Age **C**. Pregnancy/ milking mothers **D**. Severity of fever **E.** Other

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6. How often do you encounter resistance to the prescribed antibiotic in typhoid patients?

    A. Frequently **B.** Moderately **C**. Rarely **D.** Unknown **E**. Others

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7. How might the use of rapid, sensitive and specific test improve your treatment of patients with typhoid?

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8. How might the use of rapid, sensitive and specific detection of antibiotic resistance improve your treatment of patients with typhoid?

EXTRA INFORMATION

Questions: (Public health officials, academic researchers)

1. What are the current challenges of typhoid diagnosis in Cameroon?

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2. What are the requirements of an effective diagnostic tool for typhoid?

    A. Speed and Accuracy

    B. High Specificity and Sensitivity

    C. Availability and Usability

    D. Comprehensive in the detection of typhoid and antimicrobial resistance.

    E. Other

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3. How feasible is the use of molecular diagnostic tools in the diagnosis of typhoid in local health centres?

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4. How can molecular diagnostic tools be adopted and integrated within local hospitals?

5. What local policies are there to build the capacity of public and private laboratories?

6. What policies govern the introduction of new diagnostic procedures into public and private laboratories?

7. What other priority diseases can benefit from rapid and cost-effective molecular diagnostic tools?

Extra Information