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Assessing Perceived Challenges to Laboratory Testing at a Malawian Referral Hospital

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Abstract. Adequate laboratory infrastructure in sub-Saharan Africa is vital for tackling the burden of infectious diseases such as human immunodeficiency virus and acquired immune deficiency syndrome, malaria, and tuberculosis, yet laboratories are ill-integrated into the diagnostic and care delivery process in low-resource settings. Although much of the literature focuses on disease-specific challenges around laboratory testing, we sought to identify horizontal challenges to the laboratory testing process through interviews with clinicians involved in the diagnostic process. Based on 22 interviews with physicians, nurses, clinical officers, medical students, and laboratory technicians, technologists and supervisors, we identified 12 distinct challenges in the areas of staff, materials, workflow, and the blood bank. These challenges underscore the informational challenges that compound more visible resource shortages in the laboratory testing process, which lend themselves to horizontal strengthening efforts around the diagnostic process.

INTRODUCTION

Approximately 63% of the world population lives in low-income countries, which share a disproportionate burden of communicable diseases. A strong laboratory infrastructure is vital for tackling the burden of infectious diseases such as human immunodeficiency virus (HIV) and acquired immune deficiency syndrome, malaria, and tuberculosis in sub-Saharan Africa.[1] The presence of HIV is confirmed with a laboratory test, and disease progression and timing of antiretroviral therapy traditionally requires either assessment of viral loads or CD4 counts. Tuberculosis and malaria can only be definitively diagnosed through laboratory testing[2]; furthermore, drug-resistant tuberculosis requires additional testing and is currently severely underdiagnosed.[3,4] A blind diagnosis of these types of diseases, one that is not confirmed by a laboratory test, can lead to a significant risk of inappropriate treatment and a waste of already scarce resources. Inappropriate treatment will likely be ineffective in treating the disease, resulting in poor patient outcomes, and it may even be harmful to the patient or lead to drug resistance. Laboratories are essential in the diagnostic process in resource-poor settings, yet they are not well supported or well integrated into diagnostic and care delivery processes in low-resource countries.

Existing laboratories in low-resource settings are often under-resourced and underused. The shortage of both personnel and supplies in laboratories contributes to lengthy turnaround time, the time required to receive the results after ordering a test—often days. Thus, the decision to order laboratory tests is often a choice between accuracy and expediency. As a result, diagnoses are often made using less reliable and less valid signals and symptoms.[5] Malaria, for example, is frequently diagnosed based on symptoms instead of a test result, though symptoms may overlap with other diseases. A study of almost 200 health facilities in Uganda found that roughly 25% had a functioning microscope, but in those facilities, only 35% of malaria diagnoses used a malaria slide examination.[3] In Tanzania, a study of 4,670 patients diagnosed with severe malaria found that fewer than 50% had a blood smear result consistent with the disease.[6] This can result in worsened health status for patients inappropriately treated with antimalarials for a condition such as bacterial sepsis, which has a similar presentation.[1] Inaccurate diagnosis and treatment not only can result in poor patient outcomes but can also distort measures of disease incidence in the population.

The laboratory testing cycle includes tasks that span multiple departments and involve many different medical and laboratory personnel. The common perception of laboratory testing considers only the testing process itself, termed the analytical phase. The complete laboratory process, defined as the "total testing cycle" or the "brain-to-brain" process,[2,7,8] begins with the initial physician decision to order a laboratory test and ends when the physician acts on the laboratory results. The pre-analytical phase involves the steps after the test is ordered and before the sample arrives at the laboratory, while the post-analytical phase captures the processes after the results have been reported.[7] Although the analytical phase is the most visible and occurs in the laboratory, the other two phases occur in the patient wards and capture the laboratory–provider dynamic; they have also been found to contribute significantly to laboratory turnaround time.[9] Misunderstandings and frustrations hinder the relationships between laboratory personnel and health-care providers in the ward; laboratories are overwhelmed with test orders, and thus may take days to process a test, while inaccurate sampling and ordering of laboratory tests by health-care providers create further delays. The resulting prolonged turnaround time diminishes the role of the laboratory and reinforces the use of less accurate but more expedient alternatives for diagnosis.

Although there is anecdotal evidence of friction in the relationship between the medical ward and the laboratory, its nature and causes have not been thoroughly reported in the literature. Rather, the literature on laboratory challenges in low-resource settings focuses on disease-specific laboratory processes and interventions, such as microscopy for malaria, often addressing generalizable testing issues only in the context of a specific disease.[10–13] Understanding workflow barriers,

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perceptions of challenges, and the interactions between the laboratory and providers in low-resource settings is an important step to improving the use of laboratory testing across all conditions and diseases. This study aims to gain a more granular understanding of the specific challenges encountered in laboratory testing in a low-resource setting hospital laboratory, specifically the laboratory at Kamuzu Central Hospital (KCH), Malawi, as perceived by healthcare providers engaged in the diagnostic process.

MATERIALS AND METHODS

Study site. The setting for this work is KCH, a 710-bed government-operated tertiary referral hospital in Lilongwe, Malawi.[9] It serves an area that includes approximately 5 million people, and it includes laboratory and radiology facilities as well as four operating rooms and an on-site pharmacy. In 2010, it served roughly 50,000 inpatients and 275,000 outpatients.[14] The KCH laboratory conducted more than 240,000 laboratory tests in 2010. The most common tests requested were malaria (66,601), full blood count (FBC) (32,909), and CD4 counts (13,947).[15]

Study design and methods. This study, conducted during June 2015, used semi-structured key informant interviews to qualitatively explore perceived barriers around using and delivering laboratory testing services. Interview questions were designed to gather information from key personnel involved in the continuum of processes that constitute the total testing cycle.[16] Recruitment was done through an announcement during morning handover meetings in the laboratory and in the medical department, which were attended by laboratory technicians and clinicians, respectively. A phone number was provided for interested individuals to call and schedule an interview time. Of the 25 people working in the laboratory, all attended at least one of the morning handover meetings in the laboratory when the study was announced. The same was true for the medical staff, which consisted of four medical teams with two doctors on each team. Nursing staff were notified of the study by the nurse in charge. Interviews were conducted by the first author (Lia G. Petrose), who was trained in obtaining and analyzing qualitative data in the context of community health assessments. All volunteers contacted the interviewer through the phone number provided to make an appointment for the interview. There were no exclusion criteria. Interviews lasted approximately 25 minutes each. Light refreshments and pay-phone coupons were provided to participants. Interview questions were open-ended to facilitate follow-up questions and encourage an exploratory and thorough discussion. The following questions were used to initiate discussion:

1. Do you see laboratory testing as an important component of diagnosing and treating patients?
2. Describe your role in the laboratory testing process.
3. Who else is involved in laboratory testing? What roles do they serve in the testing process?
4. How can the laboratory testing process at KCH be improved?

Interviews were conducted in English, one of the two official languages of Malawi and the language in which all secondary and tertiary education takes place. Verbal informed consent was obtained from participants. Interviews were audio recorded and subsequently transcribed for analysis. Ethical approval for this study was obtained from the University of Malawi College of Medicine Research Ethics Committee; the study was designated as quality improvement by the University of Pittsburgh Institutional Review Board.

Analysis of data. Audio recordings of interviews were transcribed into Microsoft Word, and a codebook was constructed using the editing method described by Crabtree and Miller.[13] As part of this process, two of the authors developed independent codebooks, then harmonized them into a single codebook through an adjudication process. Each code was given a definition that corresponded with the challenge or theme it highlighted. All transcripts were then independently coded using this common codebook. The coders then met to discuss differences in the assignment of codes until consensus was reached. The themes determined through this process were then recorded in a master spreadsheet, which was used for the final analysis. To represent common themes, the coders identified excerpts of the coded interviews that best illustrated the idea of each theme.

RESULTS

A total of 22 interviews were conducted with individuals in the following roles: nurses (three), physicians (five), medical students (two), laboratory technicians (four), laboratory technologists (four), laboratory supervisors (two), and clinical officers (two). Of these, 21 interviews were audio recorded. The subject of Interview 14, a nurse, wished not to be taped.

Twelve subthemes emerged, each labeled with a code and corresponding to perceived challenges present throughout the diagnostic process. These were grouped into larger themes to capture primary workflow processes in the total testing cycle and to aid in the discussion of challenges with similar root causes. These themes and their subthemes are presented in Table 1.

Themes include the two major resource inputs of laboratory testing, staff and materials, as well as the interaction of the two in terms of workflow. Finally, there was consensus that a specific function of the laboratory, supporting the blood bank, faced distinct challenges. Subthemes corresponded with specific challenges that were identified by interviewees within each of these themes. During analysis, some subthemes were merged as distinctions between them blurred. Subthemes are categorized and defined below followed by representative quotes from the interviews that reflect these concepts.

TABLE 1
A comprehensive list of all themes and subthemes

Theme	Subtheme
Materials	Machine-related issues
	Reagent-related issues
	Challenges around test tube usage
	Paperwork issues
Staff	Staff shortages
	Staff turnover
	Staff training
Workflow	Delays in processing
	Delays in sample delivery
	Communication
	Missing data and samples
Blood Bank	Blood donations

Materials. The lack of resources in the laboratory and the ward is a persistent challenge according to staff interviewed for this study. Lack of resources includes issues with machines, the lack of reagents, and challenges surrounding paperwork and other testing supplies.

Machine-related issues. Interviewees talked about problems with machinery that involved keeping equipment functional.

> *I think the major problem is the machines. Last year we ran close to six months without running a PCR test because the machine was down.* Interview 7 (laboratory staff)
>
> *As a referral hospital lab, we are supposed to have like a backup. When one equipment is down, another should be working. But sometimes we do face challenges whereby maybe we have one equipment, that equipment is down, and it means we can't provide that service. So that also affects diagnosis of patients in the wards.* Interview 5 (laboratory staff)
>
> *Sometimes the printer itself gets damaged .... So it means you will be borrowing printers from other departments ... [which] means that department is suffering. Paperwork is piling up. They are waiting for the printer as well.* Interview 6 (laboratory staff)

Reagent-related issues. Subjects discussed challenges with obtaining an adequate, uninterrupted reagent supply to run tests in the laboratory.

> *You can see that there are some things that are not running in the lab because of lack of reagents. You can come as a motivated person to the lab but just find that there is nothing to work with. You don't have any motivation again. Supplies, we need supplies so we can continue running tests.* Interview 4 (laboratory staff)
>
> *Most of the time, we don't have enough reagents. Or when we get orders, we get too much. And when we get too much we find out they are expired soon .... And this might force us to use the expired reagents.* Interview 9 (laboratory staff)

Challenges around test tube usage. The use of an incorrect test tube when a sample is being collected from the wards was cited as a laboratory challenge.

> *Sometimes you don't have the actual bottles that you need, like right now we do not have the red top bottles I used for U&Es [Urea and Electrolytes]. So you have to take the FBC [Full Blood Count] bottle ... it has the liquid inside to keep the blood from clotting, so you have to wash that out and put the sample in. So I am not even sure if I am contaminating the sample by doing that.* Interview 11 (medical staff)

Paperwork issues. Subjects discussed the shortage of stationery and the resulting misuse of the existing stationery.

> *Most of the time we improvise [for test orders]. We just write on plain paper, the name, the time, sometimes we may forget the date or the ward of the patient so that means that form will go nowhere. Or in the receiving box in the lab, it can be dumped anywhere. And you go to [the] pediatrics [pigeonhole], [and] find it is not there. And you see in medical there are a lot but you don't even check.* Interview 17 (medical staff)
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> *It has been a challenge because people just use any scrap paper. So that scrap paper will have inadequate information. Because after you have done the test, you need to know the clinical condition of the patient with your results because you need to correlate. When you have a form, it's like you are guided. But with the plain paper, you are not guided.* Interview 5 (laboratory staff)
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> *Paper forms are difficult to track. If you're looking for a sample from two weeks ago, you have to figure out what date and you have to go find out the lab ID number and you have to go through all the forms and search for that particular number. Usually when you get queries, it i[puts] a bit of strain on us. Just dealing with one query will take a while because it is paper forms.* Interview 3 (laboratory staff)

Staff. Staff allocation and training are salient issues in the diagnostic process that lead to many challenges on their own or exacerbate the problems reflected in the other themes.

Staff shortages. Interviewees identified a lack of clinical and laboratory staff as a problem contributing to challenges around laboratory testing.

> *I think the major challenge is that we are understaffed during the night and we are overwhelmed by the endless need for blood transfusion. There is always someone waiting for the lab.* Interview 7 (laboratory staff)
>
> *The nurses know they are supposed to do it [drawing blood] but they can't because they are overloaded and understaffed. You can't expect like two nurses to be taking care of fifty something patients, it's absurd.* Interview 12 (medical staff)

Staff turnover. Subjects identified staff turnover as a problem resulting in inconsistent testing procedures and communication challenges.

> *Not staff but you know we have a lot of students that are working here so most of the time you have a new batch of students doing rotations so every time there is a change, there is also a change in the viability of the samples. So better training and better communication is important.* Interview 3 (laboratory staff)
>
> *You find that you have new employees, even if you try to organize training, you find that a pool of people who have that information, they are sent somewhere ... there is high staff turnover. There is need of continuous training, but because this is a central setting, you have these challenges going on as well.* Interview 8 (laboratory staff)

Staff training. Subjects discussed inadequate staff training for drawing samples and operating different types of equipment as a challenge in the laboratory.

> *And if we look at who is trained properly, I don't think there are many. The persons at the Lighthouse [HIV clinic], I know they are properly trained. But in other cases, they just depend on their medical*

background, what they learn in school. You also see the type of samples that come, the volume, it is usually not [what] we are looking for. So training is important. You have to train everybody that is involved in collecting the samples. Interview 4 (laboratory staff)

Workflow. The transportation of samples and results between the laboratory and patient wards is burdened with confusion and unnecessary waiting. Samples wait to be taken to the laboratory, samples wait at the laboratory to be processed, doctors wait for results, and patients wait for treatment.

Delays in sample delivery. Subjects discussed the amount of time it takes for the sample to be delivered to the laboratory after being drawn and the time it takes for it to be processed.

It is not evenly distributed. For instance, in the morning, you receive a lot of samples. Then lunch hour, you don't receive any samples. In the afternoon, we receive very few samples. Sometimes we receive samples very late in the afternoon, it's like they have been collecting samples from morning until now, just piling the samples. Later, we find a lot of samples coming to the lab, so where were these samples throughout the day? Interview 1 (laboratory staff)

They are supposed to be in a cold chamber and delivered as soon as they are collected. But most of the times they are batched. Like from 8-10 [am], that is when they bring the samples. But every analyte has different properties. Some once you collect them, they will either deteriorate or combine with other substances and not give you the results that you need. So transportation is another thing that we need to fix, considering time and exposure to some other things that can affect the results. Interview 4 (laboratory staff)

Because you will have something that was signed for at ten in the morning, and for Biochemistry, we are supposed to separate samples within two hours of them being taken but you see something that was taken at eight twenty-six in the morning but it arrives at the lab at four, four thirty. So, the minute you say old sample, they'll say, "but I just brought it here now" and you have to try and explain that the fact that you just brought this in now does not make this a fresh sample. The fact that it was taken at eight twenty-six in the morning makes it an old sample. Interview 3 (laboratory staff)

Missing data and samples. Subjects discussed problems associated with missing data (e.g., sex, age, and name) when laboratory tests are ordered and missing results or missing samples as challenges faced in the laboratory.

We see missing data, missing results, and this is somehow not fair for the patients. We take the sample and the patient expects to have the result and to be told what is the problem and whatsoever. So to me, I feel if we can improve on missing things and also the amount for each specific type of test, it will be very very much better. Interview 16 (medical staff)

Some of the machines, when we are logging in the information of the patient, it requires sex as well as age to give you the right reference range. So if that information is not there, the machine will just give you a general reference, which is not good, because it can show somewhere that it is abnormal but maybe it is within the range. Interview 5 (laboratory staff)

Those [orders] that do not have complete information .... The main problem with that is you will give blood to the wrong person. It has happened in the past. And, you know, blood, if you don't give to the right person, it can cause fatal effects. A patient can die because of the wrong transfusion of blood .... That is why we insist to have correct information and complete information. Interview 10 (laboratory staff)

Delays in results processing. Subjects discussed the amount of time it takes for the results to be retrieved from the laboratory and delivered to the ward as a challenge.

It takes a long time for those people to come and check the results. One thing is that they do not know when the results are ready, so they are sometimes walking up and down and up and down so many times. Interview 1 (laboratory staff)

Sometimes, there are a lot of doctors and nurses in the lab. Anybody just walks in .... The pick-up of results is a big issue .... We need to minimize the amount of non-lab personnel that comes into the lab .... They come, I am busy, they ask me to stop what I am doing to assist them, which consumes much of the time that I have. Interview 4 (laboratory staff)

Then we have patients still waiting for results. Patients are still in the ward and they should be discharged but the hospital still has to give them food and everything. And then our hospital is always piled up with patients and then they fail to admit another patient because someone is waiting for a simple test like FBC. Interview 7 (laboratory staff)

Communication. Subjects described a lack of communication, (e.g., effective communication between the laboratory and ward, clear role definition) as a challenge in the laboratory testing process.

To start with, we need to come up with a standardized system, whereby the attendants or the nurses really need to have a proper way of ordering tests and the attendants or the nurses should really know their roles when it comes to collection of samples, or transportation of samples to the lab. Interview 1 (laboratory staff)

Looking at the diagnostic process, at the end of the day, it is the patient who benefits ... it is very important to bring up something that would encourage that communication. Maybe having a few meetings every fortnight. Between almost everybody. Doctors, nurses, and lab people, and there are probably some from the pharmacy. So you would have it where you would concentrate on the flow process, not just on the management issues .... If it is a blame game, then we will start with the blame game at the beginning. But having those meetings every fortnight, I am telling you the blame game will go. Interview 2 (laboratory staff)

So when you are analyzing samples maybe you can get higher potassium and you will say it's okay, it's

because the sample stayed long in the ward before it was transported to lab. So maybe our friends in the ward maybe they don't understand why we are saying once you have collected the sample, that sample should be transported to the lab as soon as possible. Maybe we can orient these people so they understand better the requirements in the lab. Maybe we can improve that challenge. Interview 5 (laboratory staff)

Blood bank. The blood bank, operating inside the laboratory, has its own set of unique problems and challenges. The interviewees pointed to the lack of blood donations as a root cause of this problem.

We tried to say if we have a shortage of blood, can we ask family members [of] the patient who is sick, to come and donate blood. So it was working, it was working well, until the last three weeks when MBTS [Malawi Blood Transfusion Service] says no, we cannot continue with this program because it conflicts with their policy. Their policy says that they should only get blood from voluntary donors and in this case, it is not really voluntary because they are forced to donate because they want to save their family members. Interview 10 (laboratory staff)

And here in Malawi, most of the people don't like donating blood. It is our problem here. So we really need to conduct big big campaigns so that people know why it is important for them to donate blood. Interview 13 (medical staff)

No, the people donate. But when the blood gets into the hands of the blood transfusion service, they charge the hospital for each pint. So the issue is . . . they want to get more money, because if we bleed ourselves, we will not need to buy from them. Interview 20 (medical staff)

We have some times when we have good supply of blood and when we are in critical shortage of blood. MBTS mainly collects blood from students, especially secondary school students. So when these students are on holiday, they have no one to draw from because these students have gone to their respective homes. During these periods, we suffer critical shortages . . . . But when they are back to school, the supply automatically increases. So when schools close, that is when you have problems. Interview 10 (laboratory staff)

DISCUSSION

This study summarizes the challenges identified by KCH laboratory and medical staff regarding the diagnostic process. A correct and timely diagnosis, produced by a healthy laboratory infrastructure, is integral to the patient and the treatment he/she will receive. Each theme highlights an important area of challenge in the diagnostic process that directly or indirectly detracts from the quality of medical care at KCH. Although each subtheme is specific, many are also crosscutting and interdepartmental in nature, indicating the need for a collaborative and systematic approach to addressing these challenges.

Throughout the interviewees' discussions of the diagnostic process, two silos emerge: the laboratory and the medical ward. As indicated in the theme of communication, these departments operate independently of one another, with separate staff, separate leadership, and very little interaction. Most interviewees identified improved communication between the two, in the form of attendance at morning meetings, as a possible intervention for many of the challenges they identified. One interviewee mentioned that a meeting between the two groups every 2 weeks would eliminate the "blame game," which is a result of each group's limited understanding of the workings of the other.

A recurring challenge is the inability of the laboratory to conduct key tests due to a lack of reagents or machine malfunction. This problem was raised by most interviewees and is captured in the two subthemes, reagent supplies and machine-related issues. Interviewees identified many contributors to this challenge, some of which are lack of machine maintenance and delays in deliveries of reagents, which can lead to short shelf lives once they actually arrive at the laboratory. Both laboratory and medical personnel cited this challenge as one that puts pressure on the capacity of the laboratory. As a result, medical personnel are forced to send tests to other peripheral laboratories that perform the role of a substitute when the KCH laboratory is not functioning. This is less than ideal, interviewees mention, because restrictions around referring these laboratory orders, such as payment or a daily quota, can limit the diagnostic ability of clinicians, leading to overall worse patient outcomes. This could be a result of resource scarcity or poor management, but nonetheless contributes to the dwindling confidence of KCH medical professionals in their laboratory infrastructure.

Blood transfusions and their associated tests account for a significant volume of the laboratory workload[15]; they involve not just laboratory and the medical wards but also the Malawi Blood Transfusion Service (MBTS) that provides blood daily to the laboratory. Blood shortages were a salient problem mentioned by several interviewees. However, perhaps because the transfusion process involves many key players, these shortages are even further compounded by other challenges, including understaffing during the night shift when most samples come in or poor communication between the laboratory and the ward, which leads to further delays in transfusions. Conversely, while the transfusion process is compromised by these structural difficulties, the process itself has spillover effects into other tests that are conducted by the laboratory. Several interviewees mentioned that the high volume of transfusions that must be done, especially during the night shift, hinders their ability to conduct other tests that may arrive during that period. Most interviewees pinned the cause of nationwide blood shortages on the dependence of MBTS on blood donations from secondary school students and lamented its choice to ban donations from patient guardians.

Several interviewees also identified missing information as a significant barrier to the diagnostic process. The use of paper forms, which depend on the hospital's often low supply of stationery, can create gaps in the communication between the clinician who orders the test and the technician who runs the test. This can lead to exaggerated or inaccurate results that are based on a confounded understanding of the patient. Even if the results are accurate, they may end up in the

wrong ward due to incorrect labeling and never return to the clinician who ordered them. When results are missing, clinicians will often go down to the laboratory themselves to search for them. This can lead to interruptions in the laboratory, and more time is wasted as the technicians go through their own paper logbooks searching for the old result. The effect seen is frustration and distrust from both parties, a major contributor to their strained relationship. Many interviewees also stated that medical personnel are unsure when the results are completed because there is no easy way to alert them and no set time for people to come check for results. This contributes to a delay in returning the results to the physician, which in turn keeps patients in the hospital longer than may be necessary and delays treatment.

The challenges identified in the interviews underscore the interplay between resource shortages and informational problems. When there is a shortage in paper supplies, there is consequently often missing data on the laboratory order forms. Each challenge reinforces other challenges, contributing to worsening the quality of health-care delivery at KCH. This compounding of issues highlights the dual challenge facing this facility as well as others operating in resource-constrained environments: not only are there shortages of resources (equipment, staff, etc.), but also existing resources are not always deployed effectively. Again, for example, because of the inconsistent supply of laboratory order forms, health-care professionals are accustomed to providing incomplete requests. Thus, even when resources are available, incomplete test orders can render a sample untestable and result in wasted paper, test tubes, and provider time, ultimately resulting in delayed care. Our focus on the diagnostic process as a whole, as opposed to just the laboratory or medical ward, has given insight into these deeper problems that plague this crosscutting process and contribute to lower quality of care.

Limitations of this study include selection bias, interviewer bias, and generalizability. Individuals voluntarily opted to participate in the interviews, and therefore may not represent the entire KCH medical and laboratory staff involved in the testing process. We attempted to address interviewer bias by asking the same standardized questions to all participants and allowing the participants themselves to steer the conversation. Finally, we only interviewed laboratory and medical staff at a single referral hospital in Malawi, but respondents identified challenges that have been identified in other low-resource laboratory settings.[1,3–6,12]

The results of this work provide evidence and context for challenges in the laboratory diagnostic process, motivating the development of interventions to improve the laboratory workflow and stature within the hospital. The choice to capture the pre- and post-analytical phases by including providers from the medical ward and laboratory staff, recognizes that challenges at any point in the process, regardless of location, undermine the ability of laboratory testing to improve health-care delivery and health outcomes. Because laboratory is a crosscutting health-care service, we hope that the findings of this work will promote horizontal health system improvements that will affect care across all clinical domains.

Although an intervention focused on the analytical component of the process, primarily the workings of the laboratory, could alleviate some of the challenges identified above, a more effective intervention would involve the diagnostic cycle as a whole. At its core, the diagnostic cycle involves the transfer of information (test orders, samples, and test results) between individuals and wards.[14] As a result, many of the challenges identified are informational in nature, whether related to communication between medical and laboratory staff or the completeness of test paperwork. To this end, an informatics-driven intervention designed to engage both providers and laboratory technicians may improve communication and efficiency between these services and address many of the delays highlighted in this report. Specifically, we propose the introduction of mobile technology that could be used at the bedside to both review test results as well as order tests. Working in conjunction with a laboratory information management information system, this would address the many challenges in the pre- and post-analytical phases described in this investigation. There are also resource barriers such as equipment shortages that must be addressed in parallel to translate any communication improvements into improved confidence and reliance on laboratory testing.

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