Developing Laboratory Systems and Infrastructure for HIV Scale-Up: A Tool for Health Systems Strengthening in Resource-Limited Settings

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Abstract: The rapid scale-up of HIV care and treatment in resource-limited settings has overwhelmed many public health laboratory services already burdened with human resource shortages, an aging and inadequate infrastructure, and a lack of quality systems. There is, however, a growing appreciation of the opportunity to use HIV-related laboratory strengthening as means to strengthen health systems in general. We briefly describe ongoing efforts to integrate HIV laboratory support into HIV care and treatment systems, thereby strengthening laboratory systems in support of both HIV scale-up and overall health systems strengthening.

Key Words: clinical laboratory, health systems strengthening, HIV/AIDS, resource-limited setting

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Over the past decade, the role of clinical laboratory strengthening as a critical component of the global response to the HIV epidemic has been increasingly recognized. Accurate and timely clinical laboratory services permit earlier HIV diagnosis, staging, identification of adverse drug events and opportunistic infections, and monitoring response to therapy. The rapid scale-up of HIV care and treatment in many resource-limited settings, however, has overwhelmed public health laboratory services already burdened with human resource shortages, an aging and inadequate infrastructure, and a lack of quality systems. Although there has been remarkable progress in the development of assays suited to low-resource settings, including point-of-care (POC) tests, weak sample transportation and laboratory management systems have left many laboratories unable to support HIV clinical services with timely, consistent, and reliable service.

The integration of HIV-related laboratory services within HIV care and treatment clinical programs is an important approach to closing this gap. There is also growing appreciation of the opportunity to use HIV-related laboratory strengthening as a means to strengthen health systems in general. The World Health Organization (WHO) has defined health systems as "all organizations, people and actions whose *primary intent* is to promote, restore, or maintain health"[1] and has called for national public health laboratories to be seen as part of the broader national health system.[2] To meet this objective, WHO urged member states to develop comprehensive national laboratory policies and formulate national strategic plans for tiered laboratory networks (Fig. 1, Table 1), with basic laboratory services at peripheral clinical sites and more sophisticated laboratory assays at centralized reference laboratories.

The United States President's Emergency Plan for AIDS Relief (PEPFAR) has also recently broadened its approach to include laboratory systems strengthening. Although PEPFAR I focused on providing basic lab services needed for HIV diagnosis and care, PEPFAR II considers broader aspects such as quality management systems, equipment maintenance, training, and infrastructure.[3] In view of these broader efforts, we describe ongoing efforts to strengthen laboratory systems in support of both HIV scale-up and overall health systems strengthening.

HUMAN CAPACITY DEVELOPMENT

The lack of adequately trained personnel is often the most significant rate-limiting step in providing quality laboratory services and clinical services in resource-limited settings. In Nigeria, south-to-south workshops have been successfully used to build laboratory capacity. These workshops are conducted at a regional training laboratory in Africa rather than in the United States or Europe. The training laboratory is usually housed within a tertiary laboratory facility and allows both novice and experienced African laboratory staff to gain practical skills through in-service training without burdensome travel costs and visa requirements. Standardized training guidelines are used to train teams of trainers who in turn train staff from lower-tiered satellite labs in their own networks. Similarly, the Centers for Disease Control and Prevention recently launched the African Center for Integrated Laboratory Training in Johannesburg, South Africa. Preservice training and ongoing site supervision, however, are additional critical components for quality laboratory and clinical services, and both remain a significant challenge in most countries.

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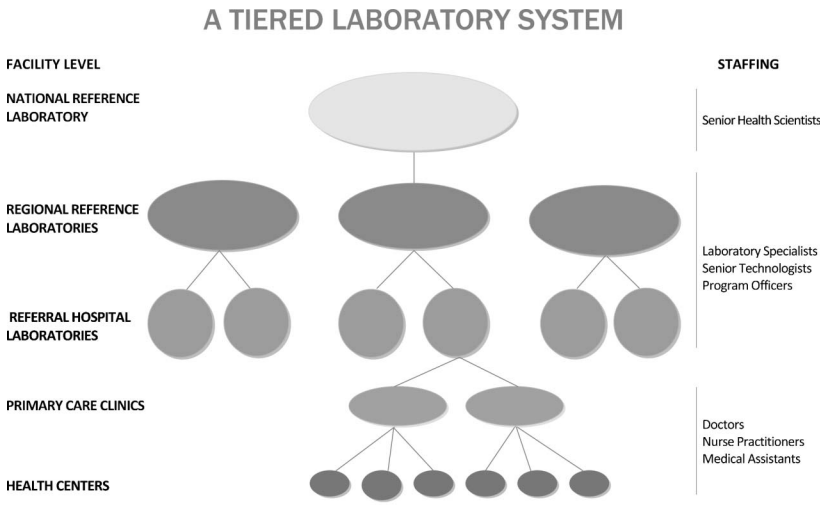

(Adapted from "The Tiered, Integrated Laboratory Network." In: Helping to Expand Sustainable Quality Testing to Improve the Care and Treatment of People Infected with and Affected by HIV/AIDS, TB and Malaria. [Report on Consultation on Technical and Operational Recommendations for Clinical Laboratory Testing Harmonization and Standardization, meeting on January 22-24, 2008, Maputo, Mozambique.] Geneva, Switzerland: World Health Organization. 2008:3. http://www.who.int/diagnostics_laboratory/3by5/Maputo_Meeting_Report_7 _7 _08.pdf. Accessed September 12, 2009.)

FIGURE 1. The tiered, integrated laboratory network.

Strategies for human capacity development and staff retention apply to laboratory and clinical staff alike and include adequate compensation, training opportunities, and opportunities to participate in research and public health evaluations. The effectiveness of salary increases on retention in laboratories has not yet been established, but a pay increase for pharmacists in Botswana, for example, did increase staff retention. In Rwanda, performance-based financing links salary to work quality and volume for health facility workers, including laboratory staff. Improvements in work environment through infrastructure renovation may also boost staff morale and promote retention.

INFRASTRUCTURE, LOGISTICS, AND SUPPLY CHAIN MANAGEMENT DEVELOPMENT

Inadequate space, lack of shelving and files, aging equipment, unreliable water and electrical supply, and frequent stockouts continue to be major infrastructure challenges to reliable and accurate laboratory services. In Ethiopia, however, there has been significant progress in building infrastructure under the National Laboratory Strategic Plan of the Ethiopian Health and Nutrition Research Institute (EHNRI). The national reference laboratory at EHNRI and 4 regional hospitals and 6 regional laboratories have been renovated

TABLE 1. Tiered Laboratory System

Test	Reference Lab	Provincial	District	Health Center
HIV serology	EIA, rapid tests, WB	EIA, rapid tests, WB	EIA and rapid tests	Rapid tests
CD4 cell count	High volume flow cytometry machine	High volume flow cytometry machine	Low volume flow cytometry machine	Ref to District Lab
Infant diagnosis of HIV	DNA PCR	Dried blood specimen (DBS) to Ref Lab	DBS to Ref Lab	DBS to Ref Lab
Viral load	RNA PCR	Refer to Ref Lab	Refer to Ref Lab	Refer to Ref Lab
HIV resistance testing	RNA PCR	Refer to Ref Lab	Refer to Ref Lab	Refer to Ref Lab
Chemistry	High volume analyzer	High volume analyzer	Low volume 'dry' *chemistry analyzer	Low volume 'dry' chemistry analyzer
Hematology	High volume hematology analyzer	High volume hematology analyzer	Low volume 'dry' hematology analyzer	Low volume 'dry' hematology analyzer
TB	Microscopy and culture	Microscopy	Microscopy	Microscopy
Syphilis	TPHA, RPR	TPHA, RPR	TPHA, RPR	RPR
Opportunistic infection diagnosis	Microscopy, serology, culture, and PCR	Microscopy and serology	Microscopy and serology	Microscopy
Parasitology	Microscopy, malaria smear	Microscopy, malaria smear	Microscopy, malaria smear	Microscopy, malaria smear
Urinalysis	Test strip and reader	Strip and reader	Test strip	Test strip

EIA, enzyme immunoassay; WB, western blot; TPHA, treponemal pallidum hemaglutination test; RPR, rapid plasma reagin.
*Dry analyzers use strips impregnated with dry reagents to which the specimen is added. They can be operated by non laboratory technologists.

and equipped, expanding the capacity for sophisticated tests such as HIV DNA assays for infant diagnosis of HIV.

Infrastructure also includes procurement and transportation systems. In Rwanda, implementing partners contribute funds to a "common basket," and the national central purchasing unit (CAMERWA) procures medications and diagnostic reagents and kits, with technical support from USAID's Supply Chain Management System (SCMS). This approach to procurement, along with the use of forecasting tools, results in fewer stockouts.

Transportation systems for samples and results need to reflect laboratory and clinical management systems and the structure of the laboratory network. Challenges include lack of an affordable courier, cold chain requirements, transportation delays, inadequate space for sample storage, and absent or unreliable sample tracking systems—all resulting in lengthy turnaround times. Ideally, a laboratory network blends a centralized laboratory system with a POC system. POC testing for the more frequently used, less complex assays such as HIV rapid testing, hemoglobin, and glucose is increasingly common and reduces the need for transportation of samples and results.

Electrical supply is problematic in some regions, and the use of solar-powered or propane-powered equipment has been an advance. For example, cold chain problems in some regions of Nigeria have been addressed via propane-powered refrigerators. Additional infrastructure challenges include lack of adequate capacity to perform laboratory equipment maintenance and the absence of a standard laboratory inventory system. The need for equipment maintenance is increasingly recognized, however, and many laboratory managers now negotiate maintenance contracts when purchasing equipment.

QUALITY ASSURANCE

Although many African countries have a national quality assurance (QA) program to ensure adherence to laboratory service standards and procedures and have participated in an HIV serology QA program, consistent QA is generally lacking in lower-tier laboratories. For example, in a survey conducted in 89 health care facilities (including 29 hospitals and 34 health centers) in the Lake Victoria region of Tanzania,[4] only 16 (18%) had standard operating procedures in place, and only 13 (15%) reported equipment calibration systems. There are very few publications of this nature, and additional surveys will be critical for planning how best to meet needs.

In Nigeria, external quality assessments (EQA) are performed for several tests conducted through the AIDS Prevention Initiative in Nigeria. There is also a comprehensive quality management plan that includes strong quality control measures, EQA, and specific training workshops with external quality specialists. The National Institute of Medical Research in Nigeria became certified by the International Organization for Standardization in early 2008, taking an important step toward accreditation. In addition to QA, EQA, and accreditation programs, on-site periodic supervisory visits by trained staff are important to improving laboratory service quality. Moreover, trained clinical and laboratory staff who provide on-site supervision can at the same time promote integrated clinical and laboratory services and further enhance program quality.

LABORATORY DATA COLLECTION AND INDICATORS

Collecting and analyzing program data on specific features or indicators allows countries to monitor progress, assess laboratory systems strengthening, coordinate efforts, and plan future HIV/AIDS activities. Basic laboratory indicators were developed by PEPFAR in 2007 and were recently revised to reflect PEPFAR II goals (Table 2). To allow for more comprehensive program monitoring and evaluation, Columbia University's International Center for AIDS Care and Treatment Programs (ICAP) has developed several data collection modules, including a detailed series of indicators (Table 2) and a standardized assessment tool to assess facility-level characteristics of ICAP-supported laboratories. The indicators will be collected routinely, and summaries of program data are provided through ICAP's Web-based database for access by key stakeholders. The standardized assessments allow for the monitoring of key facility-level characteristics such as type of testing conducted, type of equipment used, equipment maintenance schedule, QA/QC procedures, laboratory accreditations, physical infrastructure status, and supply inventory and procurement status. The implementation of laboratory information systems also strengthens laboratory capacity and permits the use of data for both laboratory and clinical program planning and evaluation. However, in supporting implementation of

TABLE 2. PEPFAR Laboratory Indicators and ICAP Laboratory Indicators

2A. PEPFAR Laboratory Indicators 2007[3]	2B. ICAP Laboratory Indicators
• No. laboratories with capacity to perform HIV tests and CD4 tests and/or lymphocyte tests • No. individuals trained in laboratory-related activities • No. tests performed at USG-supported laboratories in the areas of HIV testing, TB diagnostics, syphilis testing, and HIV disease monitoring	• No. individuals trained in serology • No. individuals trained in blood chemistry • No. individuals trained in CD4 assessments • No. HIV tests conducted • No. HIV enzyme immunoassay tests conducted • No. smear tests conducted • No. syphilis tests conducted • No. CD4 percentage tests conducted • No. HIV viral load tests conducted • No. CD4 count tests conducted • No. ALT tests conducted • No. creatinine tests conducted • No. individuals trained in serology • No. individuals trained in blood chemistry • No. individuals trained in CD4 assessments

Source (2A)—available at: http://www.pepfar.gov/documents/organization/81097.pdf, p. 186. Accessed September 2, 2009.

laboratory information systems, challenges exist, such as the need for sufficient technical expertise to maintain computer systems and allow effective use of laboratory indicator data.

HARMONIZATION

Too large a variety of laboratory equipment and reagents in a region complicates procurement and equipment maintenance. Recent efforts have therefore focused on harmonization and standardization of the minimum package of supplies, tests, and equipment needed at each level of the laboratory network[5,6] (Table 3). In addition, recognition is growing of the need for national laboratory strategic plans to specify lists of commodities and equipment to be used in each country.[7]

Implementation of such harmonization plans has begun. In Ethiopia, EHNRI oversees the standardization of laboratory commodities across the tiered laboratory network and works with SCMS to procure reagents, supplies, and equipment. SCMS has seconded staff to 6 regions to procure and monitor the inventory and consumption of laboratory supplies. EHNRI conducts on-site training on equipment maintenance and has hired and trained engineers to provide maintenance to the regions. In addition, SCMS has centralized the process of ordering replacement parts for equipment with a list of frequently required spare parts.

CONCLUSIONS: PUBLIC HEALTH LABORATORIES GOING BEYOND HIV

Although some have argued that a disproportionate amount of financial resources are going into the funding of one disease,[8] others welcome the opportunity to strengthen health systems overall, including public health laboratory systems.[9] To strengthen health systems, public health laboratories that are integrated within clinical programs serving both those with HIV and the general public are critical. Some countries have been more successful in taking steps in this direction. In Tanzania, the Ministry of Health has set up a financing mechanism that allows resources from PEPFAR and the Global Fund to Fight AIDS, Tuberculosis and Malaria to go into a common basket that supports laboratory services for the general population, including but not limited to those with HIV. Most countries, however, have not yet been able to do this, and innovative approaches, such as partnerships between the private and public health sector, will be needed to achieve international goals such as the Millennium Development Goals. Over time, stronger and more sustainable health care systems will evolve through coordinated transition plans among governments, donors, and partners.

TABLE 3. Key Points from the Maputo Declaration On Strengthening of Laboratory Systems (January 2008)[6]

Governments, multilateral agencies, development partners, professional associations, and academic institutions to recognize:

1. The burden of the priority diseases HIV, malaria, and tuberculosis.
2. The need to expand and further develop quality-assured laboratory services as part of a greater framework of health system strengthening within resource-limited settings.
3. That in resource-limited settings, several challenges have resulted in inadequate laboratory systems to support the scale-up of programs.
4. That to improve and sustain access to laboratory services, there must be an integration of laboratory support for tuberculosis, malaria, and HIV disease programs.

Source: http://www.who.int/diagnostics_laboratory/Maputo-Declaration_2008.pdf. Accessed June 21, 2009.

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