White Paper Report of the RAD-AID Conference on International Radiology for Developing Countries: Identifying Challenges, Opportunities, and Strategies for Imaging Services in the Developing World

Daniel J. Mollura, MD[a], Ezana M. Azene, MD, PhD[a,b], Anna Starikovsky[a], Aduke Thelwell[c], Sarah Iosifescu[d], Cary Kimble[e], Ann Polin, MSRS, RDMS, RDCS, RVT[f], Brian S. Garra, MD[g,h], Kristen K. DeStigter, MD[g,h], Brad Short, MLA[i], Benjamin Johnson[j], Christian Welch[j], Ivy Walker[k], David M. White, PhD[l], Mehrbod S. Javadi, MD[b], Matthew P. Lungren, MD[a,m], Atif Zaheer, MD[a,b], Barry B. Goldberg, MD[n], Jonathan S. Lewin, MD[b]

The RAD-AID Conference on International Radiology for Developing Countries was an assembly of individuals and organizations interested in improving access to medical imaging services in developing countries where the availability of radiology has been inadequate for both patient care and public health programs. The purpose of the meeting was to discuss data, experiences, and models pertaining to radiology in the developing world and to evaluate potential opportunities for future collaboration. Conference participants included radiologists, technologists, faculty members of academic medical institutions, and leadership of nongovernmental organizations involved in international health care and social entrepreneurship. Four main themes from the conference are presented in this white paper as important factors for the implementation and optimization of radiology in the developing world: (1) ensuring the economic sustainability of radiologic services through financial and administrative training support of health care personnel; (2) designing, testing, and deploying clinical strategies adapted for regions with limited resources; (3) structuring and improving the role of American radiology residents interested in global health service projects; and (4) implementing information technology models to support digital imaging in the developing world.

Key Words: Radiology, developing countries, public health, microcredit, microfinance, residency education, international global imaging, economic development, health care policy, information technology, limited-resource regions, health care disparity, radiology readiness

J Am Coll Radiol 2010;7:495-500. Published by Elsevier Inc. on behalf of American College of Radiology

[a]RAD-AID International, Chevy Chase, Maryland.

[b]The Russell H. Morgan Department of Radiology and Radiological Science, Johns Hopkins University School of Medicine, Baltimore, Maryland.

[c]Legatum Center for Development and Entrepreneurship, Massachusetts Institute of Technology, Cambridge, Massachusetts.

[d]Grameen Foundation, Capital Management and Advisory Center, Washington, D.C.

[e]Project HOPE, Millwood, Virginia.

[f]Brier, Washington.

[g]Fletcher Allen Health Care/University of Vermont, Burlington, Vermont.

[h]Imaging the World, Charlotte, Vermont.

[i]American College of Radiology, Reston, Virginia.

[j]University of California, San Diego, School of Medicine, San Diego, California.

[k]World Health Imaging, Telemedicine & Informatics Alliance, Chicago, Illinois.

[l]Applied Physics Laboratory, Johns Hopkins University, Baltimore, Maryland.

[m]Department of Radiology, Duke University, Durham, North Carolina.

[n]Division of Diagnostic Ultrasound, Department of Radiology, Thomas Jefferson University Hospital, Philadelphia, Pennsylvania.

Corresponding author and reprints: Daniel J. Mollura, MD, RAD-AID International, 2620 Spencer Road, Chevy Chase, MD 20815; e-mail: dmollura@rad-aid.org.

The RAD-AID Conference on International Radiology for Developing Countries was funded in part by the William Gatewood Fellowship Fund, Baltimore, MD.

INTRODUCTION

Limited access to radiology in developing nations has been widely documented, including a report from the World Health Organization that approximately two-thirds of the world's population lacks adequate access to medical imaging [1-6]. However, radiology is an important component of many global public health programs, including tuberculosis, AIDS-related pulmonary infection, trauma, breast cancer screening, and maternal-infant health care [7]. Historically, small teams of radiology personnel have undertaken limited service projects in different areas of the world. However, there has never been a dedicated forum to present and discuss these projects. The recent RAD-AID Conference on International Radiology for Developing Countries was designed to fill this void, and RAD-AID is a nonprofit organization and network of partnered organizations whose mission is to address the limited availability of medical imaging services in developing countries.

This white paper describes and analyzes the challenges and opportunities facing radiology in developing countries with strategies for addressing these factors on the basis of the interdisciplinary perspectives presented at the RAD-AID conference. We present 4 important components of optimizing radiology in developing countries: (1) increasing access to capital financing and business leadership for local imaging entrepreneurs, (2) designing and testing radiologic clinical models for limited resource regions, (3) improving the role of US radiology residents in overseas service programs, and (4) enhancing information technology strategies.

FINANCE, ENTREPRENEURSHIP, AND LEADERSHIP FOR RADIOLOGY IN DEVELOPING COUNTRIES

Given the cost, complexity, and skill requirements of radiologic services, the sustainability of radiology in developing countries has been a long-standing challenge. Short-term radiology charitable projects have provided some help in these regions, but a longer term outlook should incorporate local clinical and economic stakeholders to maintain and build on these efforts. We present several economic strategies to achieve sustainable radiology in developing health care systems that foster local entrepreneurs and business leaders to grow these services for local clinical health care needs over the long term.

RAD-AID supports a "radiology entrepreneurship" model that encourages local health care personnel to develop sustainable, low-cost business models that incorporate medical imaging (where needed) into the local health care economy. RAD-AID is working to facilitate this approach by creating an effective system of business administration training, impact measurement, and leadership training combined with financial loan support to radiology entrepreneurs. The Massachusetts Institute of Technology Legatum Center for Development and Entrepreneurship offers a fellowship program for Massachusetts Institute of Technology graduate students who wish to develop businesses that effect positive social change in the developing world. The use of for-profit startup ventures to effect social change is known as "social entrepreneurship," and Legatum Center fellows receive academic training, financial assistance, and business plan coaching, as well as access to online modules for continued education upon completion of the fellowship. The Legatum Center's social entrepreneurs have combined these leadership training programs with diverse funding models, including corporate partnerships and local tiered-price approaches that subsidize services to low-income areas with revenues from wealthier ones.

Access to capital and financing is a key topic in the current global economy given the instability of worldwide financial institutions in the past several years. Over the past decade, microfinance has become a strong alternative source of financing for local entrepreneurship in developing countries. Microfinance institutions provide very small loans (usually less than $200) for the development or expansion of small businesses. Microloans of this size require no collateral and are usually repaid within a year. The repaid principal and interest are then immediately recycled as new loans to keep money in the hands of borrowers. The Grameen Foundation helps microfinanced institutions gain access to various sources of funding, including guarantees, loans, and structured finance. This role increases capital liquidity in developing regions by distributing risk and increasing access to funds for local banks to provide loans.

"Microfinance-plus" models combine supportive services with financing in the microloan package, such as health education, insurance products, or business training. This model could be used for radiology in developing countries by integrating loans with radiologic training, equipment donations, and business administration mentorship. An example of a microfinance-plus model involving health services is Project HOPE's Village Health Bank, which integrates microcredit and health education. Each Village Health Bank is a group of 18 to 25 local entrepreneurs given access to microfinance capital. The members operate in a system of peer-mediated accountability for progress reports, support, and loan repayment. Since 1993, Project HOPE's Village Health Bank program has provided a combination of health education and microcredit in 10 countries, achieving a 99% repayment rate on more than 157,000 loans worth $25 million [8,9].

The unique challenge presented by medical imaging is the relatively high expense of purchasing equipment. Im-

aging entrepreneurs in developing nations are generally part of the "missing middle," defined as those needing more than a microloan but unable to access traditional credit markets. Making credit accessible to imaging entrepreneurs in emerging countries where conventional banks are not comfortable with higher risk profiles necessitates a strategy that specifically focuses on midsize loans. The risk of midsize loans could be mitigated by screening candidates, grouping radiology projects into larger pools to spread risk, and using small microcredit loans (less than $1000) for the purchase of supplies, training, and equipment repair.

Efforts are also under way to lower the cost of imaging equipment. For example, Imaging the World (ITW) has developed low-cost ultrasound equipment with programs for training and deployment of ultrasound services to rural regions. The World Health Imaging Telemedicine and Informatics Alliance (WHITIA) is working to lower the cost of radiography.

It is important to have an analytical framework for optimizing these limited resources to maximize the value of donated or subsidized equipment. One framework to address this need is RAD-AID's Radiology-Readiness, which involves systematic measurement of resources and infrastructure necessary for deploying and optimizing radiology in the developing world [10]. Radiology-Readiness is a multivariate framework accounting for infrastructure, energy needs, clinical referral networks, access to medications and treatments, economic sustainability, and information technology systems to analyze health facilities and communities for optimizing radiology's role. For example, it may not be optimal to deploy mammography if there is inadequate access to biopsy and treatment services, and it may not be effective to implement chest radiography for tuberculosis management in regions with no access to antibiotics. Therefore, the Radiology-Readiness framework aims to measure the technical, economic, and clinical context to optimize outcomes and maximize the yields of donated and subsidized resources. Where this infrastructure is lacking or underdeveloped, RAD-AID works with its partners to create an environment suitable for a sustainable radiologic service.

CLINICAL IMAGING MODELS AND STRATEGIES FOR INTERNATIONAL RADIOLOGY

Implementing radiology in regions with scarce resources requires innovative clinical approaches for patient care and training. Multiple models are now being developed and tested for delivering these imaging services. For example, the Jefferson University Research and Education Institute (JUREI) innovated the model Teaching the Teachers. In this model, physicians from the developing world are provided training through a comprehensive curriculum featuring didactic instruction and case reviews, observation in the clinical setting, hands-on training in medical ultrasound, and training in teaching techniques [11]. Training is provided in the United States over a 3-month period. After returning to their home nations, students often establish JUREI-affiliated ultrasound education centers. There are now more than 72 JUREI-affiliated centers in 55 countries on 5 continents, each using the JUREI model to provide ultrasound training locally. Donated ultrasound equipment and service support is provided to the JUREI-affiliated education centers.

Educational outcomes assessment is a key aspect of the JUREI model. Assessments are carried out using an examination administered before, immediately after, and 6 months after completion of training. The examination uses an open-ended question format, designed to simulate a real-world clinical setting. On average, scores double between the first and second examinations and remain constant at 6 months, demonstrating knowledge retention over time [11]. This model is also supported by JUREI's affiliated centers, which provide updated educational material and examinations to evaluate effectiveness of local student training.

A second clinical training model involves on-site direct instruction within the countries. For example, the Sonographer Education initiative provides direct instruction of sonography students using a long-term, formal, and comprehensive curriculum in their home countries. Sonographer Education has helped establish the bachelor's degree program in sonography in sub-Saharan Africa at the Kwame Nkrumah University of Science and Technology in Ghana.

A third model blends clinical training with low-cost adaptations for providing health care. For example, ITW has a program designed to develop, deploy, and teach low-cost medical ultrasound in rural regions of developing countries. In this model, personnel with limited medical background are taught to perform ultrasound using external body landmarks and a low-cost ultrasound unit designed by ITW. The protocols used do not require knowledge of internal anatomy and can be learned in one week by a novice student using palpable or visible external landmarks to guide the operator. As the operator sweeps the ultrasound probe across the region of interest, images are stored as short video clips. High-fidelity image compression is used to quickly and wirelessly transmit volume data in video format across even the slowest cellular networks. The images are then viewed remotely by an ultrasound expert who immediately provides an interpretation via text messaging to both the rural clinic and the nearest hospital capable of providing definitive diagnosis and treatment.

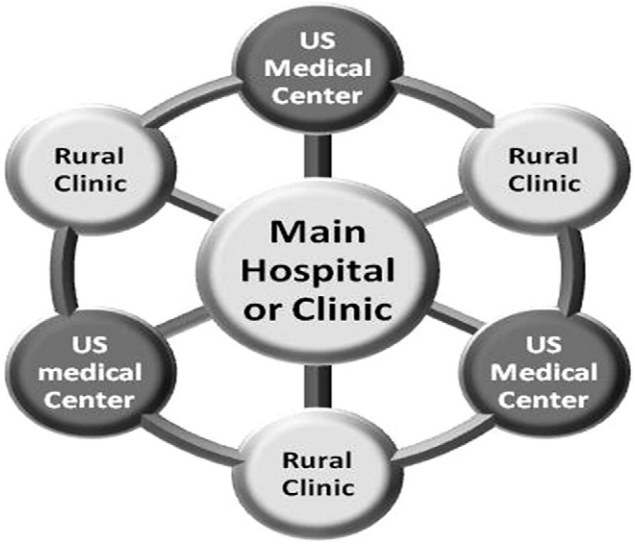

Fig 1. Clinical organizational model for efficient bidirectional information transfer, patient transport, and referral system.

A fourth clinical model uses teleradiology for imaging services in developing regions. Examples include WHITIA and the University of California, San Diego. The WHITIA model involves the implementation of low-cost, World Health Imaging System for Radiography–compliant computed radiographic systems with off-site teleradiology interpretations. Challenges to teleradiology in the developing world include shortages of imaging equipment, limited technical expertise for producing interpretable images, unpredictable reimbursement, and limited on-site experience in the use of teleradiology reports for clinical decision making. Future partnerships between radiology nonprofit organizations and teleradiology firms may be a productive avenue for addressing these challenges.

These different models can be integrated in a "hub, spoke, and wheel" model (Figure 1), in which the hub is a developing nation's medical center capable of confirming and treating preliminary diagnoses made in the rural regions constituting the wheel. The spokes represent the infrastructure required for timely and efficient bidirectional information transfer and patient transport. When needed, clinical support can be received from the developed world via teleconferencing, teleradiology, online education modules, and periodic on-site consultation.

Combining radiologic modalities may result in economic efficiencies. A recent survey conducted by RAD-AID shows a strong perception among radiologists and allied professionals that radiography and ultrasound are essential synergistic modalities in developing nations (unpublished data). This agrees with the assessment from the World Health Organization Department of Essential Health Technologies [10]. Ultrasound, radiography, and mammography are clinically complementary, and models that integrate complementary modalities may be more cost effective and provide superior care.

US RADIOLOGY RESIDENTS AND EDUCATION IN DEVELOPING COUNTRIES

The role of radiology residents in these international efforts is an important issue for implementing services in developing countries. There is a growing interest among radiology residents to perform service work abroad. Moreover, a global service component in radiology training could serve as a powerful attractant to the best medical students interested in international health and imaging.

Incorporating radiology residents into international service efforts should ideally include a structured curriculum to be integrated into residency. Curricular components could include supervised clinical rotations overseas, PACS and IT education, international health policy research, administrative internships in the operation of imaging facilities, ethics, public health, imaging of endemic diseases, and the study of health disparities.

To integrate radiology residency into overseas efforts, however, the curriculum must accommodate funding availability at academic institutions and professional educational quality standards. The funding available to institutions for graduate medical education, including radiology residency training, is made up of two primary components: (1) direct graduate medical education disbursements to pay resident stipends and benefits and (2) indirect medical education disbursements to compensate medical schools for the higher costs of patient care in educational institutions. Direct graduate medical education and indirect medical education reimbursements can only be used to support residents participating in "on-site" clinical service activities and are subject to audit by CMS. This could potentially limit the time residents devote to international electives by capping the funds available to residency programs for supporting these projects. Consequently, resident programs' budgets would need to be adjusted to accommodate electives in developing countries because direct graduate medical education and indirect medical education support could not be used for these activities. Grants, clinical revenue, and private donations are possible alternatives to support these international activities.

To meet educational quality standards, radiology residency rotations in developing countries should be evaluated by the same standards as rotations in the United States. For example, radiology residents involved in clinical decision making abroad must be supervised by qualified radiologists. Rotations must also be guided by com-

petency-based goals and objectives of the ACGME, including medical knowledge, patient care, communication skills, professionalism, systems-based practice, and practice-based learning.

An international curriculum could provide a plethora of opportunities for research initiatives and practice quality improvement projects. An example is RAD-AID's Country Report Program, in which residents help create and publish documents summarizing the radiology resources and health care systems of developing countries. Another example is the ACR's program for linking radiology residents with overseas clinical and research opportunities. From 2004 to 2008, the ACR's efforts to link residents through online forums with organizations active in developing countries yielded many volunteers but few organizations. However, in December 2008, the ACR initiated the Barry Goldberg/Maurice Reeder International Travel Grant Program, which so far has enabled 4 radiology residents to participate in overseas radiology projects for a minimum duration of 1 month.

Radiology residents have expressed a strong interest in performing service work for developing countries, evidenced by the growing rank of radiology residents volunteering through the ACR, RAD-AID, ITW, WHITIA, and other organizations. Formalizing the curriculum for these efforts could strengthen the educational experience, motivate strong applicants interested in international health, and provide key resources to execute high-quality clinical programs abroad.

INFORMATION TECHNOLOGY STRATEGIES

Digital imaging, including PACS, teleradiology, and electronic reporting, has become the standard in most developed health care systems. The efficiency, versatility, and scalability of digital imaging are all potentially useful in the developing world. Furthermore, as nondigital imaging technology becomes obsolete in the developed world, the ability to repair and replace older equipment in developing countries will become diminished as replacement parts become less available. The ability to decentralize image interpretation through teleradiology allows for greater economies of scale and access to many more experienced radiologists. For these reasons, there has been a growing effort to develop and deploy digital imaging solutions in the developing world.

The increasing global bandwidth over the past 10 years has underpinned the growth of teleradiology. However, there are still broad gaps in bandwidth between countries that mirror the gap in access to medical imaging. For example, Germany operates at an average of 10 to 15 Mbps, while Ghana averages less than 1 Mbps in most areas. The transmission of an average-sized ultrasound study would require approximately 6 minutes in Ghana, compared with less than 30 seconds in Germany. Bandwidth is improving as new infrastructure is built. However, widespread theft and resale of hardwired broadband lines have led to prioritizing wireless network solutions.

In the 1990s, early telemedicine and teleradiology research from the Johns Hopkins Applied Physics Laboratory used satellite-based communications to link health facilities. One example was a teleradiology link between an aircraft carrier and US military treatment centers via a limited-bandwidth satellite communication system. A second example from the Applied Physics Laboratory was a system to provide screening mammography to a limited-resource Native American population using a teleradiology link between a van outfitted for digital mammography and a breast radiologist at Walter Reed Army Medical Center [12].

More recent efforts are aiming to leverage cellular and wireless networks. Options for connectivity include Wi-Fi (802.11x), WiMax (802.16), and third-generation cellular (3G). WiMax (Worldwide Interoperability for Microwave Access) networks may be a reasonable option, with intermediate bandwidth and range between Wi-Fi and 3G [13,14]. WiMax bandwidth (2-4 Mbps download, 0.5-1.5 Mbps upload) is enough to support image transmission, particularly for ultrasound and radiography. WiMax, like Wi-Fi, is based on an open standard (Institute of Electrical and Electronics Engineers), making it less expensive than 3G. Cisco, Motorola, IBM, and other companies are already using WiMax connectivity to develop telemedicine services in the developing world.

ITW is testing a portable ultrasound unit that will integrate data compression and wireless transmission to link peripheral rural regions to central health facilities. This model includes a mature Digital Imaging and Communications in Medicine standard, novel image compression formats (MPEG-4 and H.264), alternative power solutions such as solar and lithium batteries, and portable cooling solutions for hardware. In Uganda, where data transmission occurs at approximately 20 kbps, ITW uses compressed video transmitted by cellular networks. MPEG-4 video compression to transmit ultrasound studies for urgent clinical applications. In these field tests, MPEG-4 compressed videos are much closer to diagnostic quality than individual images compressed by JPEG or JPEG 2000.

Data storage is a key element of strategizing radiology for developing countries. RAD-AID members have worked on cloud computing architecture for decentralized PACS that could provide a scalable, secure, low-cost infrastructure for storing radiology studies for facilities in the developing world. These systems can connect to the

wireless infrastructure for transmitting images or be used locally with maximum flexibility.

CONCLUSIONS

This white paper of the RAD-AID conference presents 4 main drivers underpinning the effective and sustainable implementation of radiology in developing countries: (1) financing with business leadership training, (2) clinical models specially suited for limited-resource regions, (3) optimized roles for radiology residents, and (4) information technology strategies. Future initiatives to address these factors include the following:

- Support radiology entrepreneurship by integrating financial capital access with clinical and business leadership training to mitigate risk, lower costs, and improve patient outcomes.
- Create economic and clinical efficiencies by integrating imaging modalities, such as radiography, mammography, and ultrasound.
- Develop a formalized curriculum for training radiology residents interested in international radiology projects.
- Implement outcomes-based measurement methods of evaluating project performance to guide future project planning.
- Include radiology technologists, allied clinical personnel, and representatives of the medical imaging device industry as well as the radiology and health care communities in developing nations for future project planning.
- Further refine RAD-AID's Radiology-Readiness assessment tool designed to identify developing nations with unmet needs for medical imaging through systematic measurement of resources and infrastructure necessary for optimizing radiology in the developing world.

REFERENCES

1. Ayieko P, Akumu AO, Griffiths UK, English M. The economic burden of inpatient paediatric care in Kenya: household and provider costs for treatment of pneumonia, malaria and meningitis. Cost Eff Resour Alloc 2009;7:3.
2. Ayieko P, English M. Case management of childhood pneumonia in developing countries. Pediatr Infect Dis J 2007;26:432-40.
3. Keefler R. Developing countries see clearly using donated imaging equipment. ACR Bull 2008;63:6-7.
4. World Health Organization. Diagnostic and imaging service. Available at: http://www.who.int/diagnostic_imaging/en/. Accessed April 23, 2009.
5. Patel A, Mamtani M, Hibberd PL, et al. Value of chest radiography in predicting treatment response in children aged 3-59 months with severe pneumonia. Int J Tuberc Lung Dis 2008;12:1320-6.
6. Reid MJ, Shah NS. Approaches to tuberculosis screening and diagnosis in people with HIV in resource-limited settings. Lancet Infect Dis 2009;9:173-84.
7. International Atomic Energy Agency. Thematic plan on diagnostic radiology. Available at http://www-tc.iaea.org/tcweb/abouttc/strategy/thematic/pdf/reports/Thematic_plan_diag_radiology.pdf. Accessed January 23, 2010.
8. Sherer RD Jr, Bronson JD, Teter CJ, Wykoff RF. Microeconomic loans and health education to families in impoverished communities: implications for the HIV pandemic. J Int Assoc Physicians AIDS Care (Chic Ill) 2004;3:110-4.
9. Smith S. Village banking and maternal and child health: evidence from Ecuador and Honduras. World Devel 2002;30:707-23.
10. RAD-AID International. Radiology-Readiness: a framework for using radiology in the developing world. Available at http://www.rad-aid.org/resource.aspx?pageName=resource-radiology-readiness. Accessed December 1, 2009.
11. Baltarowich OH, Goldberg BB, Wilkes AN, Anane-Firempong A, Veloski JJ. Effectiveness of "teaching the teachers" initiative for ultrasound training in Africa. Acad Radiol 2009;16:758-62.
12. Gitlin J, White D, Fetter J, Cook L, Linton A. Field trial of mobile telemammography: phase 1—installation and testing of equipment. Int Cong Ser 2003;1256:305-10.
13. Paolini M. Expanding the reach of health care in developing nations with WiMax. Available at http://www.senza-fili.com/downloads/SenzaFili_HealthcareEmergingWiMAX.pdf. Accessed January 23, 2010.
14. Wang X. Wireless mesh networks. J Telemed Telecare 2008;14:401-3.