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Ensuring Medical Imaging Access for All

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EDITORIAL

Welcome to the Journal of Global Radiology

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What is global radiology?

'GLOBAL radiology' is a new concept – a subspecialty of radiology that includes much more than diagnosticians and interventionists. It is an in-process international community of individuals, groups, and organizations that have thus far worked to improve access to and quality of medical imaging under many different types of headings, often with little or no direct communication with each other. Disparate individuals, non-governmental organizations (NGOs), and other organizations have a limited reach and do not have the ability to elevate technology to the next level on a global basis on their own.

Global radiology's mission is to bring these disparate resources together, to enable physicians and others to take better advantage of the knowledge afforded by medical imaging, technology, and new equipment. To achieve its broad objectives, global radiology embraces geography, public policy, cultural and economic imperatives, marketing, manufacturing, training, infrastructure, service support and much more – anything that can contribute to the availability, quality, and efficacy of radiological services in the underdeveloped world, as well as in economically advantaged environments around the globe.

Through publications, seminars, conferences, and other means, global radiology will facilitate an international exchange of skills and experiences. It will thus significantly increase the visibility of radiologists, their work, their tools and their environments, and will help to stimulate communication with, among, and for the entire radiological community.

With the involvement of policy makers, administrators, and opinion leaders, the global radiology community will assemble the resources needed to identify and deal effectively with universal shortages of equipment, infrastructure, trained personnel, education, and research opportunities.

Helping to define the size, scope, and roots of imaging problems will stimulate the development of innovative solutions, such as new techniques and equipment most appropriate to developing environments, and new business models for equipment and consumables manufacturing, business entrepreneurship, and service delivery.

Another focus of global radiology will be advocating for more and better education and training. The gaps between supply and demand for specialists – with appropriate radiological interpretive skills and an understanding of the realities of clinical practices in underdeveloped areas – will start to be closed with new medical imaging curricula and training model rules for specialists, primary care physicians, nurse practitioners, and midwives.

Ultimately, the global radiology subspecialty will be an international community of people and organizations working together to make differences in the lives of millions, possibly billions, of people around the globe.

Why "global" radiology?

No medical education or healthcare delivery program can proceed beyond primary care without diagnostic services, and imaging is a critical diagnostic tool. Even primary care physicians cannot serve their patients adequately without access to X-rays and ultrasound. And yet, according to the World Health Organization (WHO), somewhere between half and two thirds of the world's population has no access to diagnostic radiology (1).

There is a critical shortage of radiologists in underdeveloped countries. For instance, while there are as many as 100 radiologists per million people in the United States, Liberia has less than 10 radiologists in a country of 3.5 million. Those radiologists who do practice in underdeveloped environments are spread thin, with little or no opportunities for continuing education or skill enhancements, and there are very few skilled sub-specialist radiologists who can perform biopsies or angiographies. Adding to the problem is the lack of well-trained technologists that can provide badly needed professional support.

Last, but certainly not least, there are very few research exchanges between radiologists in developed and underdeveloped countries. Potentially valuable papers are written, but never reach a large audience, if they are published at all. International collaboration in authorship and editorial support can allow such research to be published in prestigious journals and have a greater, global impact.

Many of the problems affecting radiological practice on an international scale are rooted in a lack of vision, political will, and infrastructure commitment, as well as corruption, all of which have resulted in poor funding for equipment purchasing, maintenance, and replacement. There is also an absence of educational and equipment infrastructure, including adequate radiology and technologist training programs, standardization of processes, systems, or quality improvement programs, proper equipment for training as well as clinical use, and maintenance of existing equipment.

The bottom line is that thousands of physicians and other caregivers are forced to serve their patients with inadequate resources, and millions of people around the globe are suffering as a result.

Meeting the critical need for useful information

A multidirectional flow of accessible information is critical to the success of any global endeavor. Currently, articles on global radiology topics are badly scattered in various radiology journals. Additionally, many articles focus on the application of cutting-edge technology in developing environments, but the transmission of information is often unidirectional, failing to include or learn from local contexts and perspectives. There is a great wealth of valuable experience, knowledge, and expertise that is fragmented, overlooked, or otherwise not readily available to those who would most benefit from it.

The *Journal of Global Radiology* (JGR), an open-access, peer-reviewed journal available online for worldwide circulation, seeks to counteract that fragmentation of information. It will provide a global network for radiologists, business entrepreneurs, information technology experts, equipment and consumable manufacturers, policy makers, hospital administrators, public health officials, opinion leaders, educators, researchers, job seekers, and employers. Its ultimate mission is to help broaden and improve access, quality, and education in the field of radiology, and to generate increased investments in imaging technology and more effective health policies.

To achieve its objectives, the JGR's content will focus on opportunities for technology transfer, and on research, opinions and experiences that are core to health disparities between rich and poor environments. Types of articles accepted will include original research, reviews, and invited commentary, scholar twinning articles, state of radiology reports, technical notes, case reports, imaging challenges, global engagements, editorials, letters, book/software reviews, announcements, related web sites and classifieds.

Specific content could include research on innovative and cost-effective methods of diagnostic and interventional radiology; commentaries and reviews on education in radiological sciences; reports on the state of radiology in various regions and/or countries; and activities and achievements of individual radiologists and institutions working to solve access issues in and for the developing world. Articles may also identify and share developed-world experiences that can be applied to underdeveloped environments – in areas such as information technology, equipment, economics, systems, quality assurance, performance improvement, curricula, hands-on training, certification, and writing skills.

JGR will foster conversations among individuals and organizations with visions to share. It will encourage communication, collaboration, education and advocacy. The dialogue taking place in JGR's pages could lead to new ways of thinking about access, service delivery, research, quality, equipment, health policy, and turf issues. They could lead to a new consensus on global standards for equipment, competency, and training curricula for medical and paramedical staff.

A dedication to serving the global radiology community

The *Journal of Global Radiology* will be a peer-reviewed, open-access publication, with an international editorial board and a commitment to attract as many submissions as possible from all over the world.

To encourage submissions, the journal's infrastructure is being organized to accommodate the rapid publication of articles. For example, it will strive to return reviewers' comments to authors within six (6) weeks. Once the review process is complete, articles will be published in PDF format on our website, jglorad.org, under a Creative Commons 4.0 License. Articles will be fully citable, with DOI, and impact reports will be made available to authors on a regular basis. In the interest of keeping the flow of information as free as possible, JGR will not charge fees for publication, job postings, or advertisements for books, courses, or other educational or professional activities.

What can you do?

Physicians, administrators, entrepreneurs, policy makers, and other professionals involved in building the global radiology subspecialty are invited to prepare and submit manuscripts to the *Journal of Global Radiology*. We will also welcome the efforts and insights of those who would like to contribute in a reviewing capacity.

In the long run, the *Journal of Global Radiology* will succeed in its mission if it supports those working in the field of global radiology in their missions, and in sharing their important work with a broader community of colleagues. We invite your participation in building this collaborative space, and to share your ideas and insights on how this publication can be as useful and impactful as possible. We look forward to hearing and learning from you. ▢

For more detailed information about the Journal of Global Radiology *or global radiology in general, please do not hesitate to contact us at info@jglorad.org. We also invite you to visit us at our website, jglorad.org.*

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The Journal of Global Radiology
Ensuring Medical Imaging Access for All

RESEARCH ARTICLE

Implementing Diagnostic Imaging Services in a Rural Setting of Extreme Poverty: Five Years of X-ray and Ultrasound Service Delivery in Achham, Nepal

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Abstract

Introduction: Diagnostic radiology services are severely lacking in many rural settings and the implementation of these services poses complex challenges. The purpose of this paper is to describe the implementation of diagnostic radiology services at a district-level hospital in Achham, a rural district in Nepal.
Methods and Materials: We conducted a retrospective review of the implementation of diagnostic radiology services. We compiled a list of implementation challenges and proposed solutions based on an internal review of historical data, hospital records, and the experiences of hospital staff members. We used a seven-domain analytic framework to structure our discussion of these challenges.
Results: We documented the first five years of challenges faced and lessons learned by the non-profit organization Possible while implementing and providing diagnostic radiology services for the first time in a remote location. Additionally, we documented the uptake of these services through the first five years of operations. During this time, the number of X-rays performed increased 271%, while ultrasounds increased 258%. The main challenges included educating the community about the appropriate use of these services, recruiting trained providers, and coordinating referral care and consultations for higher-level diagnostics and treatment. Finally, investments in training providers and technicians, as well as investments in infrastructure, primarily the installation of solar panels to maintain a power supply, were critical to sustaining services.
Discussion: This experience demonstrates that reliable and sustained services can be deployed even in extremely remote areas and identifies challenges that other implementers may face in similar program implementation.

Introduction

PATIENTS in low- and middle-income countries lack adequate access to safe and appropriate medical machines within their local healthcare systems (1). Even where the required technology is available, machines are often unreliable. Machine malfunctions lead to wide gaps in the provision of these critically needed services. Globally, best estimates are that 47% of the X-ray machines in developing country settings do not work (2).

Ultrasound and X-ray are ideal diagnostic tools because they can meet 70-80% of all clinical diagnostic needs (3). Their absence increases the risk of misdiagnoses, treatment delays, and negative healthcare outcomes. This is of great concern for patients who have traveled long distances, at substantial cost, to receive life-saving health care. As previously discussed (4), the development of standards for ultrasound and X-ray machines deserves global attention, with consideration of the following criteria: a) reliable functionality in harsh environments, b) operational ability with unstable electricity, c) minimal emission of dangerous radiation, d) ability to be operated by non-specialists, and e) high quality imaging capabilities. However, demand for these machines has been insufficient to warrant their production (4).

The non-profit healthcare organization Possible works via a public-private partnership with the Nepali Ministry of Health and Population. Possible works in Achham District in the Far-Western

Development Region of Nepal, and operates a district-level hospital, six rural health care clinics, and a Community Health Program with 174 Community Health Workers (CHWs). Currently, there is only sparse literature on the difficulties of implementing diagnostic radiology services in low- and middle-income countries (5-7). In this paper, we will review Possible's responses to the challenges faced over the last five years of the implementation of diagnostic imaging in Achham, Nepal.

Methods and materials

Overview of implementation

We have previously described Possible's deployment of radiological services (4); here, we provide a brief overview of the deployment process. In August 2008, Possible began to offer ultrasound services at a primary care clinic in the community of Sanfebagar in Achham, Nepal. These services were provided using a GE LogicBook E machine (approximate value US $40,000) donated to Possible by International Aid (International Aid, Spring Lake, Michigan, USA). The ultrasound is equipped with a convex probe for abdominal and obstetric/gynecological scans, a micro-convex probe for cardiology and echocardiography, and a linear probe for surface organ scans. Additionally, the ultrasound is equipped with a vaginal probe for transvaginal ultrasounds. However, doctors in Nepal are not typically trained on the use of this probe. Prior to the onset of these services, there was no ultrasound capacity in the region (8). Subsequently, Possible developed protocols for machine maintenance, appropriate use, and image transfer for review by academic physicians in the United States. Possible's physicians and mid-level providers have used the machine for both obstetric and non-obstetric indications (4).

In November 2010, after Possible took over health care operations at Bayalpata Hospital, a district-level hospital in Achham, diagnostic radiology services were expanded to include analogue radiography (9). For radiography, a World Health Imaging System for Radiology (WHIS-RAD) was purchased via the Spanish company Sedecal (Sedecal, Madrid, Spain). The total cost of deployment was US $51,500 with an additional operating cost of US $5,900 per year (4).

At the time of this writing, Possible has deployed analogue film processing exclusively (4). Possible now offers one of only three radiography machines available to cover the diagnostic imaging needs of a population of over two and a half million people in the Far-Western Development Region of Nepal (10).

Study setting

Rural Achham District is home to 257,000 people who live primarily agrarian lifestyles (11). Literacy rates in Achham are 71% for males and 43% for females (11), while 59% of children under the age of five are chronically malnourished (12). According to the District Health Office, the eighth and tenth most common cases in the district are traumatic injuries and abdominal pain with 14,198 and 8,810 respective cases in 2012, demonstrating the high need for diagnostic radiology (13).

Bayalpata Hospital (BH) is 36 hours by bus from the capital, Kathmandu, and is located in an impoverished, rural area with limited resources. BH has six emergency room beds, 18 inpatient beds, and 102 employees. Since Possible began operating BH, over 218,000 patients have been treated. For the Nepali fiscal year from August 1, 2012 to July 31, 2013, BH treated 44,366 patients. Female patients accounted for 64% of diagnoses made at BH, while the remaining 36% were for male patients. The hospital employs 16 nurses, 17 health assistants, and five doctors, all of whom are Nepali.

Data collection and analysis

We conducted a retrospective observational review of the implementation experience of diagnostic radiology at BH from July 16, 2009 to March 14, 2013. BH's historical data, hospital records, and internal operations records were used to compile a list of implementation challenges and solutions. Data collection at the hospital takes place as follows:

- Patients are registered, given a patient ID number, and their demographic information is collected.
- Doctors, mid-level providers, and nurses record patient diagnoses and interventions in paper registers allocated to each department, identifying patients by ID number.
- The data and technology officer enters most of the data from the paper registers into an Access database on a daily, weekly, or monthly basis, depending on the department. De-identified data is then compiled into monthly summary sheets, which were reviewed for this study.

In addition to the retrospective data review, BH staff members were invited to participate in qualitative interviews to share their opinions and reflections on the implementation challenges and successes faced by the hospital. Additionally, blog posts related to ultrasound and radiography on Possible's website were reviewed.

The challenges were subsequently divided into the seven discussion domains of Possible's mortality and morbidity conference, derived from the Ishikawa method (14, 15):

- *Clinical operations* – Concerns with patient flow, intake, or processing in clinical departments, and/or laboratory, radiology, or pharmaceutical operations;
- *Supply chains* – Challenges in obtaining reliable supplies of quality medicines or equipment;
- *Equipment* – Issues in the functioning, quality, or availability of equipment and medical devices;
- *Personnel* – Factors pertaining to training, professionalism, management, or collaboration;
- *Outreach* – issues and opportunities in recruiting patients into timely and appropriate care through community engagement;
- *Societal* – Challenges faced by gender, caste, economic, or other social status;
- *Structural* – Factors related to infrastructure such as roads, telecommunications, educational or healthcare facilities.

This report was initially developed as an internal document to be reviewed by the Possible team. Subsequently, colleagues asked that we share our findings with the broader radiology and global health communities. No additional risks or data collection were required for the drafting of this publication. As such, ethics review was not deemed warranted.

Results

Core utlization statistics

Since the initiation of diagnostic ultrasound and radiography services at BH, 10,084 X-rays and 3,968 ultrasounds have been performed (Figure 1). Diagnoses of illness requiring X-ray and ultrasound have also increased as shown by the increasing number of fracture and cholecystitis diagnoses (Figure 2).

Implementation lessons

The implementation lessons learned from Possible's five years of experience have been summarized and divided into the seven domains described in Table 1 and Figure 3 (Page 4).

Implementation lesson 1: Clinical operations

Difficulty obtaining consults with experts in radiology

When doctors feel an X-ray or ultrasound is beyond their skill-level to diagnose, limited options exist for consultation. This is of particular concern with ultrasound at hospitals like BH, where doctors estimate learning about 95% of diagnostic procedures from more specialized providers. Ultrasound and X-ray training in Nepali medical schools is limited to a 15-day posting in the radiology department.

For consultations at BH, doctors were able to consult with one another and send images to senior providers in Kathmandu. Doctors also had the ability to consult academic physicians in the United States via email, although this was challenging due to time differences and the ability to send notification that a consultation was required. This function was further hampered by Internet disruptions due to

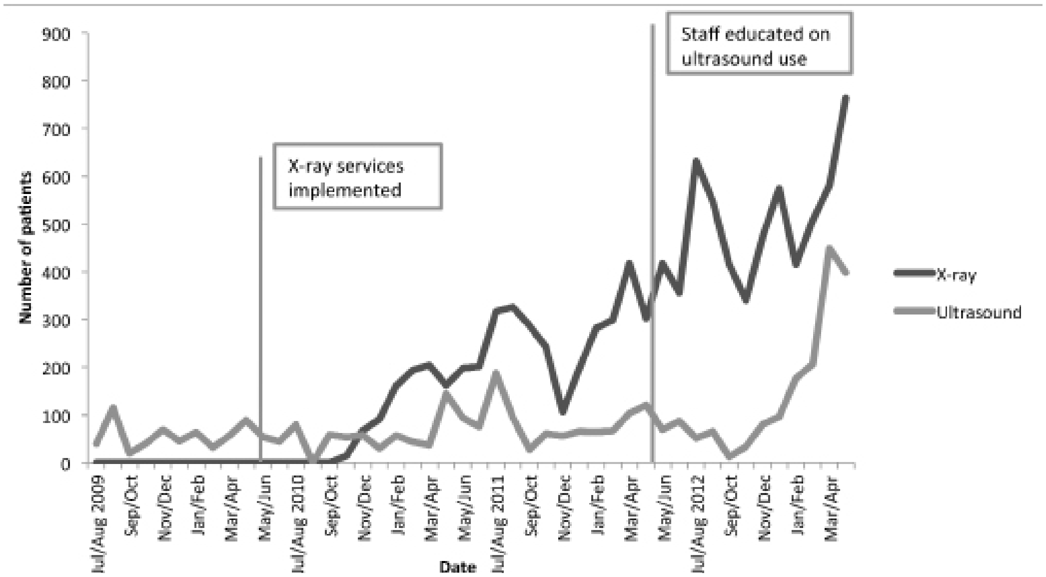

Figure 1. Time series of number of X-rays and ultrasounds with arrows indicating key events

From the first 12 months of services to the most recent 12 months for which data was reviewed, X-rays performed increased 271% and ultrasound increased 258%.

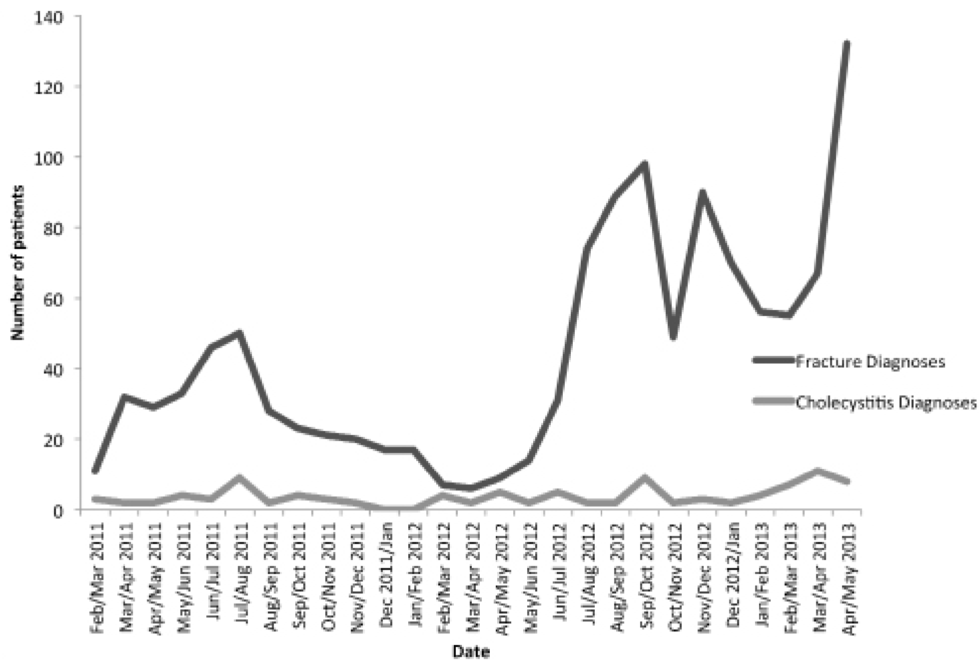

Figure 2. Time series of fracture diagnoses, and cholecystitis diagnoses

From the first 12 months of services to the most recent 12 months for which data was reviewed, fracture diagnoses increased 252% and cholecystitis diagnoses increased 168%.

storms, and the poor image quality of photographed X-rays. Doctors reported that they would prefer to use consultations more frequently if they were more easily accessible.

Clinician time and workflow

Increased community awareness in Achham and beyond led to an increase in the demand for ultrasound services, particularly for obstetrics (see Figures 1 and 2). To meet this demand, one doctor was designated in the outpatient department to perform ultrasound for the majority of their day. However, this solution detracted significantly from other services in the outpatient department and the emergency department, because fewer doctors were available to treat patients in these departments.

Implementation lesson 2: Supply chains

Purchasing and servicing

The decision of where to procure an X-ray machine involved many complex considerations. Most X-ray suppliers sell to urban markets that do not face the same challenges of rural areas. Many machines available tend to either be low-cost and non-durable, or high-cost with high maintenance and electricity needs. Possible worked to obtain the WHIS-RAD from a reliable supplier (Sedecal, Madrid, Spain) and negotiated a reasonable warranty. When the motherboard was eaten by mice and destroyed, Sedecal replaced it in a timely fashion. The current machine requires wet chemical processing, and chemicals are replaced roughly every two weeks, or when the image quality starts to decrease.

Implementation lesson 3: Equipment

Radiation safety

Radiation safety was a primary consideration when installing the X-ray machine. The WHIS-RAD that was purchased is designed to ensure the X-ray beam is permanently centered to the cassette-holder, which is backed with 0.8mm of lead. Protection of the radiology staff from scattered radiation is provided through a lead-lined console inside the X-ray room. No additional shielding is required for the walls of the X-ray room, provided they are made of material equivalent to 4 cm of concrete and the room is a minimum size of 16 m2 (16). This greatly reduced construction costs, as expensive materials such as lead walls were not required for additional radiation protection.

Inability to print ultrasound images

The current technology at BH does not allow us to print ultrasound images. Only written reports with no images are provided for follow-up visits or referrals to higher treatment centers. If an electronic consultation is required, the image can be transferred to a computer, but this is not routine. While this is an effective solution for patient care, doctors reported that patients are often disappointed to be going home without the tangible image, and subsequently request an X-ray. It is common practice in Nepal for patients to leave the hospital with a copy of their X-ray image.

Table 1.
Challenges to improving diagnostic radiology

Implementation Lesson 1. Clinical Operations	Send images for consults via email to Kathmandu-based providers, and designate provider for ultrasound services each day.
Implementation Lesson 2. Supply Chains	Obtain durable X-ray machine with reasonable warranty from international supplier.
Implementation Lesson 3. Equipment	Procure a device that minimizes X-ray scattering, and utilize written reports for ultrasound consults.
Implementation Lesson 4. Personnel	Train provider from within the organization, perform in-house repairs, Skype with trained technician, provide internal trainings, and distribute service provision.
Implementation Lesson 5. Outreach	Refuse unnecessary services, provide education, utilize ambulance, and carefully coordinate referrals.
Implementation Lesson 6. Societal	Refuse to reveal sex of fetus during ultrasound and provide revised diagnosis when explaining refusal of radiology.
Implementation Lesson 7. Structural	Install solar panels to ensure consistent power and use community health program for outreach.

Implementation lesson 4: Personnel

Lack of trained radiography technicians

The external hiring process for a radiography technician at BH produced no qualified candidates, and an internal candidate was trained. The chosen candidate trained for six weeks at a referral hospital with a trained radiography technician based at a Nepali academic medical center. This radiography aide received additional yearly refresher trainings from Nepali and non-Nepali radiographers. The radiography aide also received remote support from these trainers for complicated cases.

The radiography aide was on call 24 hours a day, and when he was absent, technicians with only a few hours of training filled in. This challenge was partially mitigated by the WHIS-RAD's relative simplicity of operation and ongoing technical support from senior technicians at Sedecal. Ongoing quality assurance and teaching were required to produce high quality images; both were challenging to develop and sustain. This lack of ongoing education and improvement frustrated providers who ordered X-rays, and it had the potential to significantly and adversely affect patient care. In addition to the training issue, the lack of staff back-up led to challenges in maintaining quality standards. Providers reported that the quality of the X-rays varied considerably depending on who was performing them and how tired or overworked they were.

Difficulty obtaining technical assistance

Maintaining the X-ray machine and performing repairs in a rural setting, with no ability to receive onsite assistance, presented a major difficulty. In one instance when a necessary repair was beyond the technical skill of the facilities manager, Possible had to contact the customer support service and request that they lead us through a repair of the X-ray machine over Skype that lasted over ten hours.

Maintenance of provider's skills

With only one ultrasound device, maintaining the diagnostic skills of all providers was challenging, and the skill level of staff using the device infrequently deteriorated. Possible tried to mitigate this challenge with trainings and the distribution of service provision to the nurses when possible, but with only one ultrasound machine, success was limited. There had been a six-week daily training for the doctors and health assistants, which resulted in increased utilization of the ultrasound by providers (Figure 1).

Implementation lesson 5: Outreach

Increasing understanding of limitations of radiology

The study district is a radiology resource-poor area, and doctors reported that patients frequently requested radiologic services that may or may not have been indicated. To manage this demand, providers refrained from overuse except in instances where the patient had traveled extremely far or had seen no improvement from prior interventions. This required training on the part of staff in respectful reassurance and patient education.

Connecting urgent cases with treatment

During the study period and continuing to present day, there are limited options for quickly connecting patients with urgent healthcare needs to hospitals in rural Nepal. Possible operates an

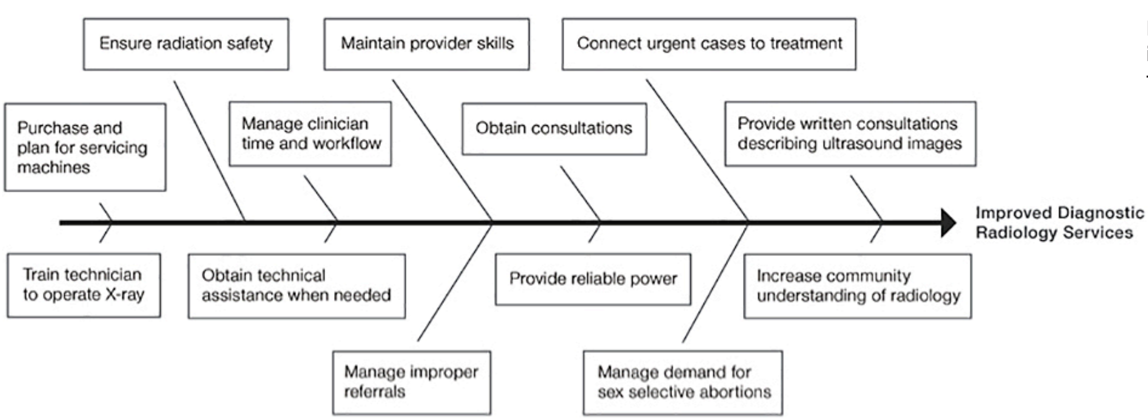

Figure 3. Solutions leading to improved diagnostic radiology services

ambulance service, but many villages are inaccessible by road and patients must be carried on stretchers. Referrals require careful coordination, taking into consideration the financial limitations and burdens placed on the patient.

Implementation lesson 6: Societal

Demand for sex-selective abortions

Women in the community faced strong societal pressure to provide their family with sons, leading to an increased value placed on male children. Sex-selective abortion is illegal, but widely practiced throughout Nepal (17). BH would not reveal the sex of the fetus in an attempt to mitigate the factors encouraging sex-selective abortion. Providers reported that this sometimes prompted women to seek ultrasound and abortion services elsewhere.

Improper referral by private providers

Due to a lack of proper training, and clinical misunderstandings about the diagnostic capabilities of ultrasound and X-ray, private medical clinics referred patients to BH for an ultrasound or X-ray with assurance that this would treat whatever problem they were struggling with. When a trusted member of the community has referred them to us, it is difficult to convince community members that these are diagnostic tools and not treatments themselves. Possible's response has been to provide the patient with an accurate diagnosis and rationale for why no radiology services are indicated.

Implementation lesson 7: Structural

Powering the machines

In a region with frequent power outages and voltage fluctuations, providing a steady supply of electricity to run the X-ray and ultrasound machines was a major challenge for BH staff. Both were originally equipped with batteries, but the X-ray battery failed and the ultrasound battery's capacity was limited. This mainly posed problems with emergency and obstetric cases, which required immediate use of these technologies. Following the installation of solar panels at the hospital, both devices are now able to run nearly 24 hours per day, but power availability can still present an issue, as many of the outlets are nonfunctional.

Limited follow-up

Due to poor infrastructure and a lack of coverage through cellular networks, there was limited ability to reach patients who did not return for follow-up. Patients walked long distances to obtain an X-ray, and if they were feeling better, there was little incentive to return. Although Possible utilized the Community Health Program for follow-up care, ensuring coordinated longitudinal care for patients was challenging, and a resource-heavy and time-intensive process for the Community Health Program.

Discussion

During Possible's five years of experience implementing diagnostic radiology services, major challenges have been overcome, yet obstacles still remain to consistently providing high-quality services for the wide variety of cases presenting to BH. This paper sought to describe these challenges, and demonstrate the solutions that Possible has deployed in response; many challenges remain.

Key to Possible's success have been the investment in training providers and radiology staff, a refusal to sacrifice on the quality of machines purchased, and the phased implementation of solar energy during the review period to provide reliable power. The deployment of radiography proved much more challenging than ultrasound, primarily due to the larger machine size and power demand of the system, and increased safety concerns. Initially only analogue radiography was deployed, though a computed radiography machine has been installed and complete digitization is now in process.

The inability to recruit trained radiography technicians in remote rural locations has been previously described, and it is estimated that less than 50% of X-rays are taken by trained technicians worldwide (18). Subsequent to the writing of this paper, Possible hired a Proficiency Certificate Level radiographer with formal training, allowing for two staff members at all times. While ultrasound does not require a trained technician, its efficacy is wholly dependent on the training and skill of the medical provider, which is frequently low. This is a challenge that providers in low-resource settings have faced (19). Although Possible's current response of training inexperienced providers onsite has functioned well, ultrasound services would be improved with the hiring of full-time personnel trained in ultrasound.

The quality of ultrasound and X-ray machines purchased remains critical to ensuring the sustainability and safety of Possible's radiology services. Previous success with the WHIS-RAD, the same system purchased by Possible, has been described by researchers in South Africa (5). Current literature and WHO guidelines emphasize the importance of maintaining an independent power supply for X-ray and ultrasound devices (20), but the process of implementing solar power to increase the capacity to provide reliable power after battery failure has yet to be described. Additionally, the challenge of obtaining technical assistance and performing repairs continues to require creative solutions in resource-poor settings. While much of the medical technology remains non-operational in resource-poor settings, a recent review of repair requests from resource-poor hospitals demonstrated that 66% of these repairs could be performed onsite with electronic access to assistance, tools, and only modest financial resources (21).

Our results show that the greatest difficulties in implementation have occurred with outreach to the community, societal relations, clinical operations and personnel. Increased demand by the community for diagnostic radiology has been reinforced by societal pressure to obtain an ultrasound and increased referrals by private providers. Of particular note, a recent study in Nepal has noted that the desire for sex-selective abortion continues to impede efforts to implement ethical ultrasound services (22). While improper referrals, demand for services, and lack of follow-up care are persistent implementation challenges faced by Possible, a review of the literature revealed no information on other providers facing these issues, reflecting the dearth of information on the implementation of diagnostic radiology in limited-resource areas.

Providing appropriate referral care for complex cases, which either cannot be diagnosed or cannot be treated by the staff at BH, remains a significant challenge. As the reliability of Internet access in Achham increases, one potential solution for increasing diagnostic capabilities at BH is to utilize telemedicine more frequently for consultation. Even with the increased diagnostic potential provided by telemedicine, the coordination of referral services will need to be expedited, as the majority of the burden of coordinating care currently falls on the patient. Additionally, the lack of digital X-ray and printable ultrasound will continue to impede the referral process until a successful scale-up is completed.

A limitation of this report is that it was conducted at a single site within a single cultural and socio-economic context, limiting the generalizability of our results. Additionally, the methodology was limited to a review of historical data, hospital records, and internal operations.

Future implementation science studies of diagnostic radiology in rural areas should document unique strategies for overcoming infrastructure challenges, patterns of ultrasound and radiography use, effective strategies for utilizing telemedicine for treatment and diagnosis, and successful systems for the training and retention of providers. While Possible's efforts took place in an area of Nepal with limited radiology services, implementation science can also provide approaches to scaling up these services in areas where basic radiology already exists.

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Conflict of interest

MF is employed by a non-profit healthcare organization (Partners HealthCare System) that manages academic and non-academic medical centers and hospitals, and receives revenue through private sector fee-for-service medical transactions and funding through public sector research and philanthropic sources. SH, RS, DS, and DM are employed at an academic medical center (Brigham and Women's Hospital) that receives public-sector research funding, as well as revenue through private sector fee-for-service medical transactions and private foundation grants. SH works in partnership with a nonprofit healthcare company (Possible) that delivers free healthcare in rural Nepal using funds from the Government of Nepal and other public, philanthropic, and private foundation sources. SH is also employed part-time at a public university (University of Washington). BD is employed at an academic medical center (Yale-New Haven Hospital) that receives revenue through private sector fee-for-service medical transactions and funding through public-sector research and philanthropic sources. ST and RB are employed at a public university (Tribhuvan University) that operates an academic medical center which receives revenue through private sector fee-for-service medical transactions and funding through philanthropic sources. BG is employed by Possible, while RS and DS serve as advisors to Possible, and receive no compensation. DM is also employed at a separate academic medical center (Boston Children's Hospital) that receives public-sector research funding, as well as revenue through private sector fee-for-service medical transactions and private foundation grants. DM is a faculty member at a private university (Harvard Medical School). DM is also a non-voting member of Possible's board of directors, but receives no compensation.

All authors have read and understood the *Journal of Global Radiology*'s policy on declaration of interests, and declare that we have no competing financial interests. The authors do, however, believe strongly that healthcare is a public good, not a private commodity. ☐

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COUNTRY REPORT

Imaging in the Land of 1000 Hills: Rwanda Radiology Country Report

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Introduction

RWANDA is an equatorial country in central Africa (Figure 1), and part of the East African Community of Burundi, Kenya, Uganda and Tanzania. It is a small country, just over 10,000 square miles. Its population of nearly 12,000,000 makes it the most densely populated state in continental Africa. Rwanda's capital, Kigali, is a mile-high city. Its elevation makes the climate much cooler and more comfortable than a typical equatorial climate. The average annual temperature is 20.5 degrees Celsius with a narrow range – April, the coldest month has an average temperature of 20 degrees, whereas August, the warmest month has an average temperature of 21.5 degrees. Economically, Rwanda functions as a subsistence agricultural country but has been actively striving to emerge as a middle-income country. Its primary exports are coffee and tea.

In 1994, the majority Hutu population carried out mass genocide of the ethnic Tutsi minority In a coordinated slaughter committed by neighbors against each other, and with low-technology weapons like machetes, nearly 1,000,000 people were killed in 100 days (1). The country was devastated. Immediately post-genocide, Rwanda was one of the poorest countries in the world with nearly 70% of the population living below the poverty line (2). Until 1997, Rwanda had the lowest life expectancy of any country in the world (3). The physician work force was depleted due to the direct and indirect consequences of the Rwandan Genocide. Since this time there has been a steady economic recovery (4), along with remarkable medical recovery. Average life expectancy nationwide, only 27 years in the early 1990s, has now reached 63 years (3).

Since the 2012 publication (5) highlighting its advances, radiology in Rwanda has benefitted from the capital infusion that has helped to propel the overall growth in the economic and health sectors. As of 2012, there are five national referral hospitals, 41 district hospitals, one military hospital and 451 health centers (6). The health centers are staffed primarily by nurses, while the district hospitals are staffed by general practitioners (graduates of medical school without a post-graduate education). Of the 625 total physicians in the country in 2011, 150 had completed residency (3).

The radiology environment

Radiologists in Rwanda

There are 11 practicing radiologists in Rwanda (Table 1), and one additional retired radiologist. There are six Rwandan nationals and five 'ex-patriot' radiologists.

Of the Rwandan nationals, all practice in Kigali. One works principally at the university-based public hospital, University Central Hospital of Kigali (CHUK). Four of the Rwandan radiologists split time between a partially private hospital (King Faisal Hospital) and the Rwandan Military Hospital (RMH), and one is in private practice in Kigali. None of these radiologists were trained in Rwanda. Some were trained in Europe (Belgium and France), and others were trained elsewhere in Africa (Kenya, Tanzania, and South Africa).

Of the five ex-patriot radiologists, one is Tanzanian and was trained in Tanzania, one is American, two are Ugandan, and one is Indian. The Tanzanian and American radiologists are funded by the Human Resources for Health Grant, and both work at CHUK. One of the Ugandan radiologists works in the south at the University Teaching Hospital of Butare (CHUB). The other Ugandan radiologist, along with the Indian radiologist, works in private hospitals in Kigali.

Only one radiologist in the country has a full-time academic appointment, with some having honorary appointments. The medical community looks to African journals for publication, although there are a few researchers, particularly the Minister of Health, who have collaborated internationally and published in top medical journals.

Technologists in Rwanda

There are 118 technologists or "radiographers" in Rwanda. All have their primary training from the University of Rwanda College of Medicine and Health Sciences, and received an Advanced

Figure 1. Rwanda Map No. 3717 Rev. 10.
United Nations, Department of Field Support, Cartographic Section. June 2008. Retrieved from http://www.un.org/Depts/Cartographic/map/profile/rwanda.pdf.

Diploma in Medical Imaging Sciences. Any technologist who desires further training must obtain it out of the country. Reportedly, five technologists have Bachelor's degrees from varying universities, as does one sonographer. Sonography, however, is largely performed by physicians.

Diagnostic and interventional skills

X-ray

a) No x-ray limitations

Computed tomography

a) Essentially, anything that can be done with CT is done in Rwanda, including cardiac imaging, angiography, etc. At this time, no CT colonography is performed.

Ultrasound

a) In the imaging community, FAST, abdominal and pelvic ultrasound and venous vascular ultrasound are performed regularly.
b) There is no advanced arterial vascular ultrasound (e.g. for renal artery stenosis).
c) FAST scans have been taught by outside organizations to internal medicine, pediatric, surgical and emergency residents with some success.

MRI

a) MRI is only available in the private sector. As the Rwandan government owns a portion of the private King Faisal Hospital, access with public insurance can be attained in certain circumstances.
b) Traditional diagnostic MRI is performed.
c) Interventional procedures, including MRI arthrography, have not yet been utilized.

Angiography

a) To date, there is no conventional angiography being performed.

Fluoroscopy

a) Basic fluoroscopy examinations, including VCUG, cholangiography, HSG, barium swallow and follow through, fistulography, IVP and pediatric enema, are performed.
b) In the public hospital there are not sufficient materials to perform adult enemas. Imaging rectal tubes, contrast bags and tubing are not stocked. Barium and air reductions procedures are not yet performed.

Other intervention

a) Minimal interventional procedures – predominately ultrasound guided – are performed on an ad-hoc basis. There is currently insufficient staff time, as well as investment in interventional materials, to provide a significant interventional service.

Power supply

According to Rwanda's chief energy supplier, the Energy Water and Sanitation Authority (EWSA), energy consumption in Rwanda is 85% from biomass, 11% from petroleum products, and only 4% from electricity (7). After major investment, there has been a tripling of the access rate to electricity in Rwanda from 5% in 2005 to 18%

in 2014 (7). The goal is for 70% access by 2017. This is compared to Africa's average of 40% access (7).

The cost of electricity is high and most is sourced by hydropower, leaving Rwanda's energy sector vulnerable to drought. The government has also utilized diesel generators, which, despite their high cost, have helped to expand the supply. The result is a cost of between US $0.14-0.25 per kWh (depending on time of day and tax-exempt status) (8), as compared to a regional cost of around US $0.10-0.12 per kWh (9). The government has had to subsidize the costs in order to maintain current growth rates (7).

Inconsistency in the power supply is also a source of frustration. A 2008 report indicated that Rwanda experienced 80 days per year without power (10), and data in 2011 suggested four days per month without power (11). Many hospitals also utilize power generators and uninterruptible power supply (UPS), which can back up in case of power failure, although this is typically for controlled shutdown time rather than prolonged continued use.

Radiology equipment in Rwanda

The majority of high-end equipment in Rwanda is found in Kigali. Equipment service contracts depend on the suppliers, as well as the original negotiation. A large majority of the equipment in Rwanda is manufactured by Siemens (Siemens Healthcare Global, Germany; Table 2, Table 3).

Table 1. Radiologists in Rwanda, 2014

Country of Origin	Countries of Training	Number
Rwanda	Belgium, France, South Africa, Kenya, Tanzania	6
Uganda	Uganda, Germany	2
Tanzania	Tanzania	1
India	India	1
United States	United States	1

Table 2. Radiology equipment in Rwanda, 2014

Equipment	Private	Public	Other
MRI	2	0	0
CT	2	2	1
Nuclear	0	0	0
Ultrasound	Unknown	See Table 3	
X-Ray	Unknown	See Table 3	

PACS

King Faisal hospital has had a picture archiving and communication system (PACS) installed since 2011. The PACS is web-based and accessible both locally and remotely. It is not fully backed up, and thus a recent crash resulted in the loss of patient data. Wisely, the same PACS was chosen for the 2014 PACS installation, allowing for potential intercompatibility during PACS expansions in the future. Ultrasound images are not currently being uploaded to PACS at CHUK, but further investment will eventually resolve this issue. More nodes can be added to allow centralized interpretation of images on a national level, as the number of radiologists grows sufficiently to meet demand.

MRI

There are two MRIs in Rwanda, both located in Kigali. One is a 1.5T Philips, installed in 2010 at King Faisal Hospital. This is accessible to those with private insurance and who privately pay for services. Under certain conditions, a patient with public insurance (Mutuelle de Santé) can access this magnet. A second MRI, a 1.5T Siemens, has just been installed in 2014 at Mediheal, a Nairobi-based private hospital newly opened in Kigali.

Computed tomography

There are five total CT scanners in Rwanda, three of which are located in Kigali. The busiest by far is the 64-Slice Siemens Somatom Definition, installed at CHUK in July 2011. The other publicly available scanner, a 16-Slice GE Multiplanar scanner, is located in Butare, and was installed in 2013. The first CT installed in Rwanda was the 6-Slice Siemens Somatom, installed at King Faisal Hospital in 2005. A new 64-Slice scanner, identical to the one at CHUK, has been installed at the private Mediheal clinic in 2014. No current replacement plan is in place for any of these scanners, and the scanners can go down for prolonged periods of time. At the time of this writing, the scanner in Butare is non-functional. .KFH is planning to buy a 128-Slice scanner, and Kanombe also is planning to buy a 64-Slice scanner, both by next year.

Fluoroscopy

There are six fluoroscopes in the country, with four located in Kigali, one in Kibungo in the east, and one in Butare in the south. Five are Siemens Duo Diagnostics installed in 2012 at CHUK, and two others are located at Rwanda Military Hospital and King Faisal Hospital. Additionally, a Philips Duo Diagnostic was installed at Rwanda Military Hospital in 2013. At the time of this writing in 2014, one fluoroscope is being installed in Butare, and another in Kibungo.

X-ray

There are approximately 60 total X-ray machines in various hospitals in Rwanda. Most of the major referral hospitals have more than one. Of the district hospitals, 33 use an analogue system, eight utilize a digital system and two utilize both. Twenty-five are manufactured by Siemens, ten by General Electric (General Electric, USA), 12 by Philips (Philips, USA) and 12 by various other companies. It is difficult to obtain a date of installation or working condition of these machines. A recent survey demonstrated that there were various challenges in keeping the X-ray equipment functional.

Service

There is a local Siemens tech representative who can troubleshoot software and some basic hardware issues. Response time is usually same day, although given a single representative's workload, responses may arrive the following day. Local repairs and system fixes are often accomplished by the next working day. Any repairs involving parts replacement can take longer. On more than one occasion during the past year, the CT scanner at CHUK has been nonfunctional for over one month. This issue is not unique to CHUK. One problem lies in moving materials from Europe to Rwanda. Customs in Rwanda exacerbates the challenge, as materials need to pass through receiving and clearing processes before moving on to the hospital. It is rare that an issue resulting from a part that is not local to the country can be solved in under three weeks.

The MRI is also locally serviced. This young machine has been reliable to this point, with little unplanned downtime. A recent need for coolant replacement resulted in ten days of downtime.

Occasionally, the equipment functions but certain supplies are lacking. For example, the hospital may be without contrast medium or film for a month at a time. Although both King Faisal and CHUK function now with PACS, the lack of film is a significant patient-care issue for many reasons, such as their referring physician likely has no way to read an image on a CD.

Job opportunities

Radiologists

There is a clear need for more radiologists in the country, as demonstrated by the government's decision to allocate precious limited resources to creating a radiology residency. Although a full description is a topic for another paper, this residency is being created under the rubric of the Human Resources for Health (HRH) program (3). A single American radiologist has been working onsite with the local radiologists to write a curriculum, have it accepted through the relevant channels, and then recruit a first class for a four-year residency program. The program intends to utilize both local resources and supplemental e-learning in order to achieve education in all subspecialties of imaging.

At least one of the private hospitals is currently hiring for part-time work. Although the Ministry of Health is not currently advertising radiology job openings, one would likely find an interested partner in the government health sector, should they offer quality services.

Technologists

The supply of technologists currently exceeds the demand for their employment. Most are employed through the Ministry of Health or in the public sector, with a small percentage employed by private institutions. One would anticipate that as the Minister of Health continues to prioritize growth of the imaging sector, employment opportunities for technologists would also continue to grow.

Economics and imaging

Readiness for radiology entrepreneurship

To understand the local medical economy, it is important to first understand the Rwandan economy in general. There has been massive growth of the economy since 1994, and more specifically since 2003. According to the World Bank, per capita GDP was US $131.56 in 1994, US $186.64 in 2002, and at last report in 2013, it had reached US $632.76 (12).

Another measure of the economy for the purpose of potential investment is income distribution. The GINI index is a measure of income distribution and how it varies from perfect equality (13). A GINI index of 0 represents perfectly equal distribution, whereas 1 represents perfectly unequal distribution (one person would have all of the money) (13). In the late 2000s, all GINI coefficients in the OECD countries ranged from 0.24 to 0.49 (13).

The highest GINI coefficients are seen in Africa, with the world's highest in South Africa, estimated to be between 0.63 and 0.7 (14). In 1985, Rwanda's GINI was 0.289, and in 2011 it was 0.508 (15). Ten percent of the population holds 43.2% of the total income share (16). The lack of income equality, as well as overall low GDP (despite impressive growth), translates into a relatively small population who can electively purchase high-cost services.

There are high-end restaurants, cafés, hotels and private hospitals in Rwanda. Such amenities are likely accessible to less than one percent of the population. Within this rubric, a new private fertility hospital has opened with a 64-Slice scanner and 1.5T magnet. Two foreign radiologists are performing interpretations. It is unclear the number of examinations being performed, and what segment of the population is able to access these services.

Radiology market and service capacity

In a country of 12 million people, there are four clinical CT scanners in use – two in the private sector and two in the government sector. This compares with 34.3 scanners per million population in the USA in 2007, or 13.9 per million population in Canada in 2011 (17). There are, in fact, fewer X-ray machines per million population in Rwanda than there are CTs or MRIs in Canada or the USA.

The government-funded portion of the health sector is more

Table 3, Part 1. Rwanda hospital summary, 2014

Hospital	Beds	X-Ray Units	Ultrasound Units
Bushenge	143	1	2
Butaro	167	1	1
Byumba	180	1	2
CHUB	N/A	N/A	N/A
CHUK	500	4	2
Gahini	200	1	1
Gakoma	83	2 (both mobile)	1
Gihundwe	205	2(1 given to Mibirizi)	1
Gisenyi	346	2	2
Gitwe	200	1(0 functioning)	1(0 functioning)
Kabaya	130	1(0 functioning)	1
Kabgayi	400	1	3
Kabutare	235	1	1
Kacyiru	N/A	N/A	N/A
Kaduha	N/A	N/A	N/A
Kibagabaga	230	1	3(1 functioning)
Kibilizi	N/A	N/A	N/A
Kibogora	245	2	2
Kibungo	242	2	3
Kibuye	218	2	2
Kigeme	178	1	2 and 2 portable
Kinihira	300	1	2
Kirehe	154	1	3
Kirinda	N/A	N/A	N/A

Table 3, Part 2. Rwanda hospital summary, 2014

Hospital	Beds	X-Ray Units	Ultrasound Units
Kiziguro	82	1	2
Masaka	100	2	2
Mibirizi	N/A	N/A	N/A
Mugonero	121	2(1 functioning)	2(1 is functioning)
Muhima	153	1	5(2 are functioning)
Muhororo	112	1	2
Munini	65	1	2
Murunda	127	1	2
Ndera	N/A	N/A	N/A
Nemba	173	2(1 is mobile)	3
Ngarama	110	2(1 functioning)	3
Nyagatare	200	1	3
Nyamata	N/A	N/A	N/A
Nyanza	182	4(2 functioning)	3
Remera Rukoma	N/A	N/A	N/ A
RMH	250	3	3
Ruhango	128	1	2
Ruhengeri	385	2	3
Ruli	178	1	3
Rutongo	106	1	1
Rwamagana	236	1	3(1 is functioning)
Rwinkwavu	130	1	3
Shyira	N/A	N/A	N/A

developed, as the vast majority of the population earns an income that primarily grants them access only to the public system. In 2011/2012, enrollment in public insurance (Mutuelle de Santé) was 90.7% (18). In 2012/2013 it was 80.7%, and in 2013/2014 it was 73% (18). It is likely that a substantial portion of the population not covered by Mutuelle de Santé still accesses the public health care system, with far less than 10% having sufficient income or insurance to access the private sector.

However, recent legislation and regulation are encouraging private sector growth in order to expand the economy, as evidenced by the increasing appearance of new private hospitals and clinics.

Radiology volunteerism

Ideally, Rwanda would be entirely self-sufficient, and to that end the country is investing heavily in creating residencies, including one in radiology. That said, the government is realistic and knows it will be quite some time before it has the workforce to properly serve the population. For this reason there is a legitimate and enthusiastic interest in medical volunteerism.

It is critical to note, however, that Rwanda is not interested in volunteerism that is not aligned with the national goals outlined in President Kagame's vision for the future of Rwanda, Vision 2020 (19). Over the next several years, contact with any of the authors or with the Human Resources for Health leadership would serve as a first step for entre into volunteering in the system.

Internet access

Rwanda was ranked first in Africa for download speeds and 62nd globally with speeds of 7.88Mbit/s in February 2013 (20). The Rwandan Internet functions on an updated 3G system, now including 3.5G and 3.75G. An upgrade to 4G is currently well underway (21).

Internet access exists in a few major cities but is primarily limited to Kigali. Most who can afford access do so via mobile devices and USB-based modems. A 20 GB data plan with the largest provider, MTN, costs 43,000 RWF or approximately $62 US. No larger packages are readily available. One can purchase a WiMax solution, with unlimited downloading at 2 Mbit/s speeds, at a cost of $120 per month.

Although maximum Internet speeds are up to 7.88Mbit/s, these are rarely available to most people. For example, at CHUK, the largest hospital in Rwanda, the maximum download speed is quoted as 3Mbit/s. Because the entire hospital depends upon one connection, individuals usually cannot achieve download or upload speeds that even approach this number.

Disease profile and differentiating demographic and cultural factors

Rwanda was forever changed by the Genocide of 1994 and the events that followed. With the genocide, the combination of murder and exodus demolished human resources. The country was essentially depleted of physicians and of higher education. The watershed for the national turnaround was Kagame's Presidency, and Vision 2020 specifically. The plan aims to transform Rwanda into a middle-income, knowledge-based economy. So far, the country is on track to meet its ambitious goals, as the desire for systemic change seems to pervade the actions and decisions of governmental authorities. In the general population, too, there is palpable pride in the continued movement towards national improvement.

In recent years, Rwanda has seen a remarkable, unprecedented reported increase in life expectancy and decrease in prevalence of disease. The prevalence of HIV is approximately 3%, but the mortality from HIV has reportedly decreased 78.4% in the last decade (22). Farmer et al. (22) reported a decrease in mortality from tuberculosis and malaria by 77.1% and 87.3%, respectively, and a maternal mortality ratio decrease of 59.5%. Despite these incredible figures, there remains a substantial amount of tropical disease such as tuberculosis, neurocysticercosis and amebiasis, particularly in referral hospitals.

Rwanda is undergoing a transformation of health delivery with the Human Resources for Health (HRH) program, which was created in 2012 to establish and improve in-country residency training programs in many specialties (23). The program aims to move physicians from the rank of general practitioner to specialist. For the time, though there remains a paucity of sufficiently trained physicians.

As noted, the health centers are staffed primarily by nurses, and the district hospitals by general practitioners. Patients present first to health centers, and the sickest are referred to district hospitals. The most critical of these are then referred to one of the five referral centers. For this reason, cases presented at the referral centers have often reached advanced stages, allowing a view of disease not often afforded in wealthier settings.

Culture and tourism overview

Cultural attractions, languages spoken

Rwanda is a beautiful country to visit. It is one of only three countries in the world where one can 'trek' mountain gorillas, or visit them in their natural habitat accompanied by a guide - a must for any animal lover. Additionally, Nyungwe National Park offers affordable "mini-safaris" on which one can see elephants, giraffes, zebra, hippopotamus and many more animals (more information: www.rwandatourism.com).

To speak of Rwandan culture and tourism without mentioning the Tutsi Genocide would be a mistake. The country gathers every year on April 7th to memorialize those killed in the genocide (24). There is a "never again" understanding of the Genocide and a visit to Rwanda without a visit to the memorials would be incomplete (more information: www.kwibuka.rw).

To the uninitiated North American or European, the thought of a visit to Africa may conjure the image of mud huts and all dirt roads. Although such things exist in much of Rwanda, Kigali, the capital has modern hotels, predominately paved roads, a reasonably reliable power and water supply and most amenities that a traveler (or resident) could need. To those familiar with the development of East Africa this will be unsurprising, but others will be happy to find restaurants of all types – Japanese, Indian, Korean, Chinese, Italian – and most are run by an expatriate of the same nationality as the cuisine.

The official languages of Rwanda are English, French, and Kinyarwanda. In 2008, schools changed the language of education to English (25). Most of your patients will speak Kinyarwanda exclusively. Most of the educated populace speaks French, and many speak at least some English. Because the language of education has changed, the younger population is, on average more proficient in English. In Kigali, a traveler can get by speaking nothing but English. Nonetheless, a simple "Murakoze cyane" (Thank you so much) or a "Mwaramutse, amakuru?" (Good morning, how are you?) can go a long way towards breaking the ice in new conversation.

Travel access, currency, local accommodations

Methods of entering the country vary depending on your country of origin. Americans and many others with a passport valid for at least six months are allowed entry without a visa application (more information: http://www.rwandahc.org/consular-and-visa-services/visa-information-and-applications/).

There are many flights in and out of Rwanda. Coming from Europe or the USA, the typical options are KLM through Amsterdam, Brussels Airlines through Brussels, Turkish Airlines via Istanbul, and Qatar airways via Doha. Although not every airline flies every day, with flexibility in carrier, there are daily flights to Europe. It is also, of course possible to travel from within Africa, particularly from Nairobi, Johannesburg, Addis Ababa and Dar es Salaam.

Local accommodation is bountiful and ranges from the five-star Serena hotel, priced around $500 per night, to guesthouses for under $30 per night. There are also executive-style apartments for those looking at longer stays and wishing to self-cater.

Local security and safety situation

Security is given high priority nationwide. Most major shops, hotels and restaurants have guards and metal detectors for entry. Most wealthy Rwandan homes, whether occupied by Rwandans or expatriates, are gated and have guards who operate the gates and control entry to the house.

At the time of this writing, there is sufficient stability for a resident or tourist to feel quite safe in Kigali, day or night. Normal precautions against walking alone late at night should be taken, but this is no different from any typical city throughout the world.

At the time of this writing, the political situation in Rwanda is also relatively stable, and certainly in comparison to neighboring countries. There are border skirmishes with the Democratic Republic of Congo and some standing travel warnings from multiple embassies against traveling to certain border regions, but on day-to-day basis, none of this impacts the daily life of someone not living on the border. One should always check with their embassy prior to travel.

Travel within Rwandan borders is exclusively by automotive transport. Kigali has an extensive bus system, but it can be somewhat confusing for the uninitiated. For an ex-patriot or visitor with the means to purchase a car or hire a driver, travel within Kigali and throughout the country can be relatively simple given a few simple rules. The roads outside of Kigali are mostly unlit, making driving after dark a dangerous enterprise. The US embassy forbids its employees from driving outside of Kigali after 6pm. Many locals use motorcycles for short transport within Kigali. This radiologist, who has seen far too much motorcycle ("moto") trauma would strongly urge the reader never to utilize this option, no matter how tempting because of the low cost. The US embassy also forbids their use. There was an attempt in 2006 to ban the use of motos, but the outcry from their drivers and passengers caused the ban to be overturned after only one week.

Health advisories

At the time of this writing, there is a risk of contracting yellow fever in Rwanda, and proof of yellow fever vaccination is required for all entrants in the country except infants. There is also a malaria risk. Some argue that the altitude of Kigali serves as protection from malaria, but this author has seen far too much of the disease among locals and expatriates alike to accept that myth. Malaria prophylaxis is needed while travelling in Rwanda. It is the norm to sleep under mosquito nets. Although Rwandan pharmacies may at times be well stocked, the supply of a given medication is inconsistent. It is advised that a traveler bring all of his or her own medications, including his or her own malaria prophylaxis, and sufficient medication to treat traveler's diarrhea, etc. A medical worker should consider bringing his or her own HIV post-exposure prophylaxis. For up-to-date information, please consult the CDC recommendations.

Tap water is not safe to drink in Rwanda. One should consume only bottled water and clean all fruits and vegetables according to appropriate standards. The typical recommendation is to only eat cooked or peeled foods. One must weigh one's own level of risk tolerance. Most expats eat salads at restaurants, and though all regret it from time to time, a given restaurant is often consistent. Asking colleagues for recommendations is a good first step.

When to visit

Rwanda has "dry" and "rainy" seasons. The rain comes primarily from March to May, and then from September through November. I believe the typical expat would think a priori that the dry season is the more appealing. During the rainy season though, the country is beautifully lush and the rain typically only lasts about an hour of the afternoon. If forced to choose, I would likely come just as a rainy season ends, when the land is still lush, and before the long dry occurs. If one were to combine a trip to Rwanda with a safari in an adjacent country, the timing could be based on animal migrations. Overall, Rwanda is a beautiful country to visit any time of year. ☐

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Conflict of interest

DR participates in the Human Resources for Health Grant, funding for which flows through the Rwandan Ministry of Health, which is in part responsible for hiring decisions for the grant.

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RESEARCH ARTICLE

Magnetic Resonance Cholangiopancreatography in 3 Tesla: 2D MRCP vs 3D MRCP in Diagnostic Evaluation with Special Reference to Different Acquisition and Reconstruction Planes

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Abstract

Purpose: Magnetic resonance cholangiopancreatography (MRCP) is an established technique for the evaluation of intra- and extrahepatic bile ducts in patients with known or suspected hepatobiliary disease. However, the ideal acquisition and reconstruction plane for optimal bile duct evaluation with 3D technique has not been evaluated.The purpose of our study was to compare different acquisition and reconstruction planes of 3D MRCP for bile duct assessment.

Methods: 51 consecutive adult patients suspected to have pancreatico-biliary disease were examined with 3 Tesla (Philips 3 T Ingenia) system both a multi thin slice (3D) and a breath-hold (Single Shot) MRCP technique were performed. In the multi thin slice technique both source images and maximum intensity projections were examined. Two radiologists blinded to clinical information viewed both MRCP techniques independantly. Measure of correlation between each of the techniques and the inter observer agreement were computed. Coronal and axial MIP were reconstructed based on each dataset (resulting in two coronal and two axial MIP, respectively) and assessed the MIP, regarding visualization of bile ducts and image quality.Results were compared (Wilcoxon test). Intra- and interobserver variability were calculated (kappa-statistic).

Results: In case of coronal data acquisition, visualization of bile duct segments was significantly better on coronal reconstructed MIP images as compared to axial reconstructed MIP ($p < 0.05$). Regarding visualization, coronal MIP of the coronal acquisition were equal to coronal MIP of the axial acquisition ($p > 0.05$). Image quality of coronal and axial datasets did not differ significantly. Obstruction due to tumor was shown in 30% of patients, and calculi in the common bile duct were shown also in 30% of patients employing the 3D MRCP technique. Obstruction due to tumor and calculi were shown in 30% and 21% of patients, respectively, using the SS 2D MRCP technique. Sensitivity and specificity in distinguishing calculi in the common bile duct by 3D MRCP and SS MRCP were 100%, 100%, 70% and 100% respectively.

Conclusions: Although the 3D MRCP multislice technique is more time consuming than the SS MRCP breath-hold technique at a 3 Tesla (Philips 3 T Ingenia) system it is advisable to use thin slice 3D MRCP in order not to misdiagnose calculi in the common bile duct.The results of our study suggest that for visualization and evaluation of intra- and extrahepatic bile duct segments reconstructed images in coronal orientation are preferable.

Introduction

MAGNETIC resonance cholangiopancreatography (MRCP) is an established technique for the evaluation of intra- and extra-hepatic bile ducts in patients with known or suspected hepatobiliary disease [1]. It is considered a reliable, non-invasive alternative to diagnostic endoscopic retrograde cholangiopancreatography (ERCP) [2,3]. Since the first description by Wallner and colleagues in 1991 [4], different acquisition techniques have evolved. Most current MRCP techniques are based on heavily T2-weighted fast spin echo (FSE) pulse sequences, which yield a luminal image of the bile ducts that is based on the inherent signal of slow-flowing or stationary bile.

Both single-shot projections and multislice techniques are available [5], with the latter being distinguished into 2D- [6] and 3D-techniques [7]. Single-shot projections are preferred in individuals who are unable to hold their breath, such as severely sick patients or small children [7]. 3D-imaging techniques provide better image quality compared to 2D-sequences [1,8,9], even though the combination of different MRCP sequences has proven to be valuable in the assessment of bile duct anatomy and pathology [10]. 3D FSE sequences are usually acquired with the slab in coronal orientation.

Maximum intensity projections (MIP) can then be obtained in any plane [7]. Previous studies have addressed the matter of optimal slice thickness for data acquisition [11] and different techniques regarding respiratory triggering [12]. However, to the best of our knowledge, the ideal acquisition and reconstruction plane, in practical terms meaning best suitable for optimal bile duct visualization with 3D techniques, has not been evaluated. The purpose of this study was to compare different acquisition and reconstruction planes of T2-weighted 3D MRCP acquisitions for assessment of the intra- and extra-hepatic bile ducts.

Methods and materials

51 patients (30 female, 21 male, mean age 47.5 years, range 18-79 years) who were referred for liver MRI and dedicated MRCP were included in this prospective study, with approval of the institutional review board.

Inclusion criteria

Patient age equal to or greater than 18 years with suspected CBD pathologies

MR imaging technique

MR examinations were performed on a 3 Tesla system (Philips Ingenia) using dedicated multi-channel surface coils covering the abdomen. Prior to image acquisition, patients received 200 mL of a negative oral contrast agent for suppression of gastroenteric fluid signal. All patients underwent a clinical routine imaging protocol of the liver, including a respiratory-triggered 3D-MR cholangiography in the coronal (dataset A) as well as in the axial plane (dataset B) apart from 14 slices of 2D MRCP, single-shot breath-hold acquisition. Results from ERCP were considered as truth for sensitivity and specificity analysis. The specific MRCP sequences had sequential k-space filling with partial Fourier filling allowed, resulting in acquisition of central k-space lines approximately three minutes after the start of the sequence. MRCP sequence parameters are provided in detail in Table 1.

Image evaluation

Two readers independently performed image evaluation in terms of visibility of different bile duct segments up to the third order and assessment of technical quality. Readers were blinded to each patient's history and other imaging findings. A single coronal and axial maximum intensity projection (MIP) covering the central, left, right, and peripheral bile ducts was generated from each acquired MRCP dataset, resulting in two coronal and two axial MIP datasets, respectively.

Each reader evaluated the reconstructed MIP in the following way:

1, Coronal reconstructed MIP of the coronal acquisition vs. coronal reconstructed MIP of the axial acquisition;

2, Axial reconstructed MIP of the coronal acquisition vs. axial reconstructed MIP of the axial acquisition.

Depiction of bile duct segments was assessed using the following four-point scale proposed by Papanikolaou and colleagues [13]: 1, segment not seen; 2, segment faintly seen; 3, segment well seen but portion of the duct or the confluence not seen; and 4, excellent depiction including the proximal and distal portions. This scale was applied to the following sections (segments) of the biliary tract: the common bile duct (CBD), the right anterior bile duct, the right posterior bile duct, the left hepatic duct, and third-order biliary branches.

Overall technical image quality was assessed using a four-point scale proposed by Lim and colleagues [14]: 1, poor quality with severe artifacts; 2, satisfactory quality with few artifacts; 3, good quality with minimal artifacts; and 4, excellent quality without artifacts.

The two radiologists graded studies obtained with each sequence in a blinded fashion, and the paired student test was used to assess differences in technical quality and visibility of individual ductal segments of the biliary tree.

Table 1.
Imaging parameters of the respiratory-triggered fat-saturated 3D T2-weighted MR cholangiographic sequence

	Geometry	3D (Triggered navigator)	2D Single Shot (Breath-Hold)
1	Total scan duration	05.00.0 min	00.06.0 sec / slice
2	TE	926 ms	5670 ms
3	TR	80 ms	740 ms
4	Acquisition Matrix MXP	336 x 254	320 x 256
5	Acquisition Voxel MPS (axial/sagittal/coronal)	1.10 / 1.11 / 5.00	0.94 / 1.17 / 40.0
6	Reconstruction Voxel MPS	0.77 / 0.77 / 5.00	0.59 / 0.59 / 40.0
7	Scan percentage	99.20%	80.00%
8	WFS (PIX) / BW (Hx)	0.759 / 572.3	1.067 / 406.9
9	TSE Factor	80	256
10	PNS / Level	79% / Normal	50% / Normal
11	Sound Pressure Level	21.5 Hz	19.1 Hz
12	Slice Thickness	-	40 mm

Statistical analysis

Results regarding bile duct visualization and overall technical image quality were compared with a two-sided Wilcoxon signed-rank test after Bonferroni correction (with a p-value <0.05 deemed significant) in the following way:

1, Coronal reconstructed MIP of the coronal acquisition vs. coronal reconstructed

MIP of the axial acquisition;

2, Axial reconstructed MIP of the coronal acquisition vs. axial reconstructed MIP of the axial acquisition;

3, Coronal vs. axial reconstructed MIP of the coronal acquired dataset;

4. Coronal vs. axial reconstructed MIP of the axial acquired dataset.

Interobserver agreement was assessed by means of a kappa-statistic and classified as follows: a K value of less than 0.20 indicated poor agreement; K values of 0.21-0.40, fair agreement; K values of 0.41-0.60, moderate agreement; K values of 0.61-0.80, good agreement; and K values of 0.80-1.00, excellent agreement [14].

Results

Bile duct visualization

In case of coronal data acquisition, visualization of bile duct segments was significantly better on coronal reconstructed MIP as compared to axial reconstructed MIP ($p < 0.05$). This was true for visualization of the CBD, right anterior hepatic duct, left hepatic duct, and third-order biliary branches. In case of axial data acquisition, one reader observed a significantly better visualization of the CBD and left hepatic duct on coronal reconstructed MIP as compared to axial reconstructed MIP.

Regarding bile duct visualization, coronal MIP of the coronal acquisition (Dataset A) was equal to coronal MIP of the axial acquisition (Dataset B) ($p > 0.05$) (Figure 1).

Axial MIP of the axial acquisition (Dataset B) was significantly better than axial MIP of the coronal acquisition (Dataset A) for visualization of third-order biliary branches, whereas lower-order branches did not show a difference (Figures 2 and 3).

Interobserver agreement was moderate to good regarding bile duct visualization in both datasets (coronary acquisition: weighted K range 0.51-0.75; axial acquisition: weighted K range 0.42-0.67).

Bile duct visualization up to the third-order is equal on both datasets, even though the image impression is more blurred on the MIP derived from the axial acquired dataset (B). P values were calculated with the two-sided Wilcoxon Test after Bonferroni correction to compare depiction scores of coronal axial acquired datasets.

Technical image quality

Regarding overall technical image quality (including axial and coronal reconstructed MIP of a given dataset), there was no significant difference between the coronal and axial acquired datasets ($p > 0.05$). However, in the case of coronal data acquisition, detailed dataset analysis showed that technical image quality of the coronal MIP was significantly better as compared to the axial reconstructed MIP ($p < 0.05$). In the case of axial data acquisition, there was no significant difference regarding technical image quality of the reconstructed MIP ($p > 0.05$).

Intraobserver agreement regarding technical image quality was moderate to excellent (weighted K range 0.55-0.96); interobserver agreement was moderate (weighted K range 0.42-0.59).

Choice of preferred image dataset

When reading coronal reconstructed MIP, readers preferred coronal acquisitions over axial acquisitions in 66% of the readings. Regarding axial MIP reconstruction, axial acquisitions were preferred over coronal acquisitions in 80% of the readings. Intraobserver agreement regarding choice of the preferred image dataset was excellent (weighted K range 0.94-1.00); interobserver agreement was moderate to excellent (weighted K range 0.57-0.85).

ERCP showed 30% malignant obstructions, 30% calculi in the common bile duct, 8% miscellaneous disorders and in 32% no abnormalities (Table 2). A significantly higher diagnostic accuracy of the 3D MRCP technique over the SS MRCP technique ($p < 0.05$) using the McNemar's test was observed. Obstruction due to tumor was shown in 30% of patients, and calculi in the common bile duct were also shown in 30% of patients employing the 3D MRCP technique. Obstruction due to tumor and calculi were shown in 30% and 21% of patients, respectively, using the SS 2D MRCP technique.

Table 2.
Comparison of 3D versus 2D MRCP in detection of various disease pathologies with ERCP (Gold standard)

	ERCP	3D MRCP	2D MRCP
Malignant Obstruction	30%	30%	30%
Calculi	30%	30%	21%

Sensitivity and specificity in distinguishing calculi in the common bile duct by 3D MRCP coronal acquisition and SS MRCP were 100%, 100%, 70% and 100%, respectively. Interobserver agreement for 3D acquisition coronal MRCP was good for all diagnosis at a Kappa value ranging from 0.76 to 0.90, but bad to moderate for the SS MRCP at a Kappa value ranging from 0.20 to 0.63.

Discussion

To the best of our knowledge the ideal acquisition and reconstruction plane for optimal bile duct evaluation with 3D techniques has not yet been evaluated. For single-shot FSE techniques, it has been suggested that straight coronal and initial left posterior oblique images clearly depict the common hepatic duct and the left hepatic duct, whereas the CBD and right hepatic ducts are better seen in left posterior images obtained at a steeper angle [15]. In a first approach towards projection cholangiography by means of MRI in 1991, Wallner and colleagues [4] used a heavily T2-weighted gradient echo sequence for assessment of bile duct dilatation. They concluded that imaging in the coronal plane provided a good view of the biliary system, whereas no additional information was found by imaging in the sagittal plane. In this study we compared different acquisition and reconstruction planes of T2-weighted 3D MRCP acquisitions for assessment of the intra- and extra-hepatic bile ducts. In contrast to single-shot techniques, 3D MRCP has the advantage of facilitating secondary reconstructions. Coronal reconstructions were preferred, regardless of the initial acquisition plane. These findings were supported by good intra- and interobserver agreements. One of the reasons for coronal image preference may be the fact that these images are similar to image impressions of ERCP and conventional cholangiograms.

Other studies have evaluated secondary reconstruction techniques for MRCP. Schaible and colleagues [17] evaluated selective MIP reconstructions of respiratory-triggered 3D MRCP versus standard MIP reconstructions and single-shot MRCP. Single-shot and standard MIP reconstructions of 3D MRCP were comparable in terms of anatomical bile duct visualization, whereas selective MIP post-processing proved useful for detection of pathological alterations. In a retrospective study, Morita and colleagues [18] compared volume rendering (VR) and MIP of 3D-TSE MRCP sequences to define biliary anatomy mostly in patients without major biliary tract anomaly. Definition of biliary anatomy was found to be more accurate using VR reformation than MIP. However, the assessment of VR images was not the purpose of the present study. One disadvantage of VR reconstructions is that the detection degree of each structure depends on the setting of display parameters, particularly on the lower threshold of the opacity curve. Therefore, VR images need to be evaluated interactively [18].

In 1999, Boraschi and colleagues [19] compared axial and coronal 2D FSE sequences with 3D-MIP projection images in patients with suspected hepatobiliary disease. A higher global accuracy for axial and coronal FSE T2-weighted sequences was found regarding the diagnosis of the level and probable cause of biliary obstruction in depiction of small intraductal pathology, such as calculi or neoplastic lesions.

We have limited our analysis to reconstructed rather thin-slice source images, as the purpose of this specific study was to directly compare acquisition and reconstruction planes for MIP assessment. A well-known limitation of MIP is that small filling defects may be obscured due to partial volume effects [20]. Further, overestimation of ductal narrowing and pseudostricture may result from the nature of MIP reconstruction [21]. Therefore, it is important that MIP reconstructions not be appraised separately, but always in combination with the original acquired dataset, and in combination with other morphological sequences.

Conclusions

We compared different acquisition and reconstruction planes of T2-weighted 3D MRCP acquisitions for assessment of the intra- and extrahepatic bile ducts in patients with different hepatobiliary pathologies.

The biggest disadvantage of 3D imaging is its acquisition time of five minutes, compared to the short time duration of 2D acquisition.

The results of our study suggest that coronal reconstructions are preferred for visualization and evaluation of the bile ducts,. In this context, the orientation of the primary dataset (coronal or axial) is negligible.

Although the 3D MRCP multislice technique is more time-consuming than the SS MRCP breath-hold technique at a 3 Tesla (Philips 3 T Ingenia) system, it is advisable to use thin-slice 3D MRCP in order not to misdiagnose calculi in the common bile duct. Better interobserver agreement is reached employing the 3D MRCP technique. ☐

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Conflict of interest

The authors declare that there are no conflicts of interest.

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BOOK REVIEW

Radiology in Global Health: Strategies, Implementation and Applications
Edited by Daniel J. Mollura and Matthew P. Lungren
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Abstract

This book review examines Mollura and Lungren's (eds.) *Radiology in Global Health: Strategies, Implementation, and Applications* (2014). The contributors have attempted to investigate root causes for radiological service-related disparity that exists between prosperous economies and low- and middle-income countries. The book is clearly geared towards manufacturing consent among stakeholders through research-based evidence to amplify the role of radiology in global healthcare through initiation, implementation, amelioration, and developing sustainable solutions for rollout of essential diagnostic/therapeutic radiology services at population levels. This includes reducing access gaps for radiology/imaging services within industrialized countries as well.

RADIOLOGY is a crucial component of modern medicine that is often overlooked in discussions of global health. False perceptions of radiology services among medical practitioners, health care workers, and health-policy makers often confine radiology's role to patient care at an individual level only. The reality is upside down. Essential diagnostic technologies are considered an integral component of primary health care by the World Health Organization (WHO), yet billions of people worldwide are devoid of even basic X-ray and ultrasound facilities. Mollura and Lungren's (eds.) new book *Radiology in Global Health* examines the intertwined issues associated with radiology and population health goals. Contributors investigate the disparity that exists between high-income countries and low-/middle-income countries. Part I is an excellent resource for radiology planers to identify specific imaging needs for a specific population, develop a holistic concept of radiology within different levels of a health system, better understand the multidisciplinary approach of a successful radiology workforce, and ultimately develop a sustainable model of radiology services in resource-poor countries. Contributors describe RAD-AID International initiatives to scale up radiology services and foster an environment of expertise and knowledge-sharing, including strategic approaches, technical designs, and clinical models of establishing effective radiology solutions across different regional and cultural contexts. Part II focuses on dedicated clinical applications in the radiological science of global health. Each chapter presents a clear picture of the role of radiological interventions to achieve high-impact goals of public health. The boundaries of global health have been blurred in today's world, due to changing population dynamics and a significant increase in life expectancy. Sophisticated radiological investigations once thought to be provided within tertiary-level hospitals need to be provided at the community level. The use of advance imaging modalities (such as CT and MRI) and teleradiology/telemedicine technologies has the potential to introduce a model of high-level, sustainable and cost-effective radiology solutions that can be implemented across a range of resource-limited settings.

Radiology in Global Health offers the bigger picture of radiology and imaging in relation to global health. It is an immensely valuable resource for any dedicated healthcare worker involved in global health or the application of technology in health. □