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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 Sanfegabar 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 utilization 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

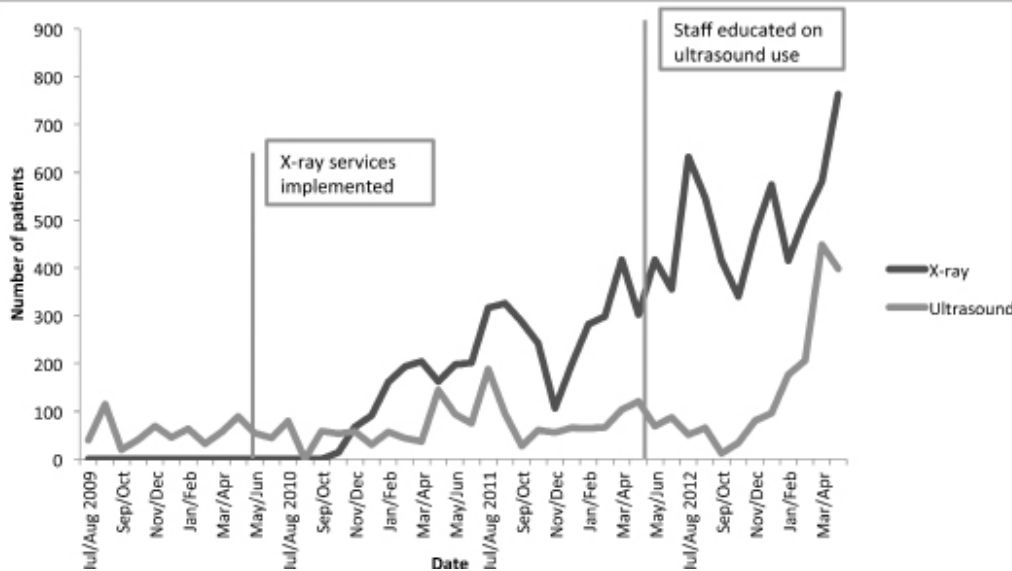


Figure 1. Time series of number of X-rays and ultrasounds with arrows indicating key events

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%.

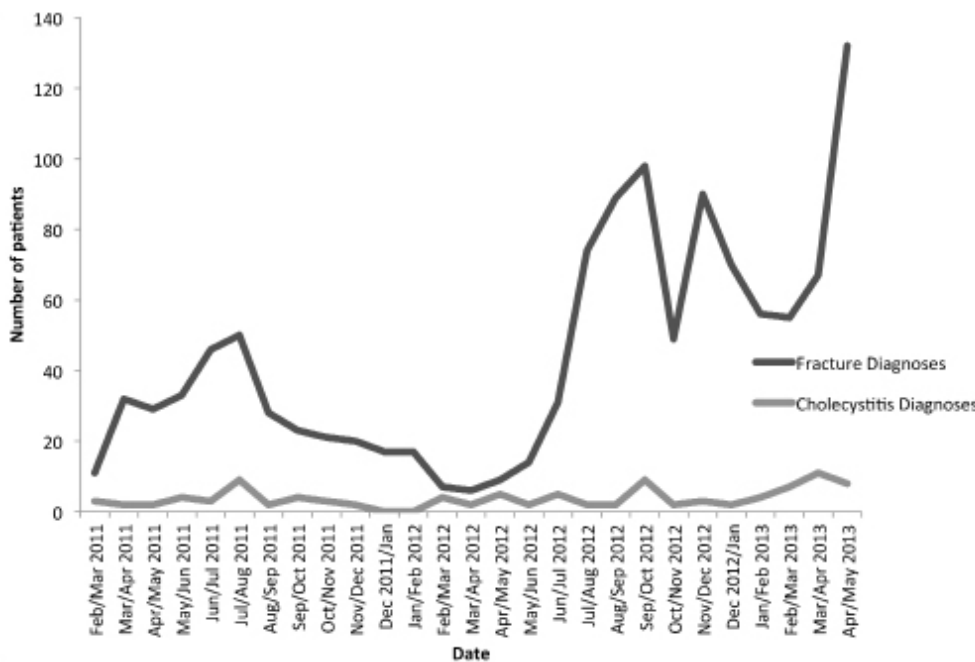


Figure 2. Time series of fracture diagnoses, and cholecystitis diagnoses

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,

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.

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.

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

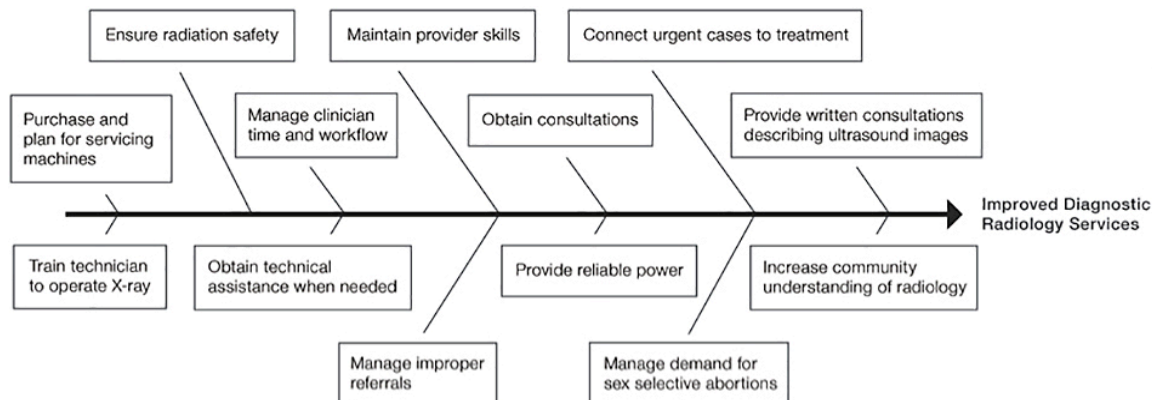


Figure 3. Solutions leading to improved diagnostic radiology services

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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