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# Experience with an ultrasound donation program in a low-income country

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## Abstract

Increasing radiology capacity in low-income countries (LIC) can improve clinicians' access to diagnostic imaging tools and improve patient care. Ultrasound (US) is important in LIC due to its lower cost compared to that of CT or MRI scans and its excellent diagnostic ability. The relative portability of the equipment makes it ideal for donation by charitable organizations. We describe our experience as a radiology-capacity-focused charity working with the Haitian healthcare system and propose strategies to increase ultrasound capacity in other poor countries.

## Introduction

It is widely quoted from the World Health Organization (WHO) that two-thirds of the world does not have access to radiology services, and recent authors affirm that access to imaging in the low-income regions of the world remains dismal (1). Yet it is estimated by the WHO that medical imaging is important in making 20-30% of diagnoses (2). X-ray and ultrasound are the most common modalities in low-income countries (LIC), where ultrasound has a uniquely important role. It is less expensive than CT and has lower operational costs than either CT or MRI while having excellent diagnostic capability for many disease processes. Smaller, more portable devices have allowed for the development of Point of Care Ultrasound (POCUS), where the exam is performed at the patient's bedside or in the field, which is particularly helpful in austere resource settings. Ultrasound and POCUS are also important in hospitals in LIC where CT or MRI are not available. It is hoped that developing ultrasound capacity will improve patient care in poor countries by improving overall diagnostic capability.

Haiti is a small nation in the Caribbean comprising the Western third of the island of Hispaniola, which is shared with the Dominican Republic. It has a population of 11.3 million with a per capita Gross Domestic Product (GDP) of $846, thereby making it the only LIC in the Western Hemisphere (3). Haitian health care spending has been decreasing for years. In 2017, it accounted for 4.4% of the national budget. This translates to approximately $13 per capita, which is less than the $15 average among worldwide LIC (4). In this article, we describe our personal experiences with the Haitian healthcare system as it relates to radiology, specifically ultrasound equipment, and propose strategies to increase ultrasound capacity.

## Radiology equipment in Haiti: the current state from a charity's perspective

Humanitarian Radiology Development Corps (HRD Corps) is a 501(c)(3) charity organization based in the United States, dedicated to building radiology capacity in underserved regions of the world. HRD Corps was founded in 2017 by several global health radiologists who initially traveled to Haiti to give lectures to the radiology residents. They quickly recognized the need for a much broader mission of capacity development, including the acquisition and maintenance of equipment and the training of personnel to use that equipment. HRD Corps has ongoing projects in LIC and middle-income countries (MIC). For radiology capacity development, LIC is much more difficult than MIC due to poor infrastructure and resources. Capacity development in LIC requires deep, long-lasting project engagement with highly dedicated individuals who are committed to this challenging work and the frequent travel it requires.

HRD Corps is a small organization of approximately 15 people comprised mainly of radiologists, radiology trainees, and technologists, all unpaid volunteers using their personal and vacation time to do this work. Each member has a full-time job in addition to HRD Corps and therefore time efficiency is key. We cherish our unique culture as an organization made up of equal directors working independently, and are always open to new members who share similar interests in this work. There are no paid administrative staff and our growth is dependent on word of mouth and our website. Operationally, HRD Corps teams and resources are organized around specific projects. Members usually work on multiple projects in unison depending on areas of expertise and foreign language skills. The travel expenses of an HRD Corps team is self-funded. Physician team members pay for themselves as well as team members who cannot afford their own travel expenses. Client sites and projects are selected based on experience from an HRD Corps assessment survey or by word of mouth. The HRD Corps operating budget for 2019 was approximately $64,000 and the fair market value of our donations to date is estimated at $1.2 million.

HRD Corps teams made multiple trips to Haiti from 2017-2018 and toured 15 private and public hospitals and clinics (5). Much of our knowledge comes from these first-hand observations of the Haitian radiology system. Haiti has a single three-year radiology residency with approximately five residents per year. The program suffers from chronic shortages of attending coverage, teaching capacity, and access to functioning equipment. As of 2016, there were reportedly 19 attending radiologists in Haiti (6). Based on word of mouth the number has likely increased and is now estimated to be between 20-30 Haitian radiologists. All interviewed radiologists report having limited access to reliable equipment.

Based on HRD Corps assessment tours across Haiti in 2017-2018, most of the 15 hospitals and clinics have ultrasound. There is, however, variability in equipment age, quality, and functionality. For example, many ultrasound machines have only one functioning probe or have lost partial functionality due to broken components such as the color Doppler, probe ports, or missing keyboard buttons. Only a few of the machines are plugged into an Uninterruptible Power Supply (UPS) to protect the electronics from the constantly varying voltage and the frequent electric power outages that occur daily across Haiti. Unfortunately, it is common that no one at the facility knows who donated the machine, who is responsible for the equipment, or who might be able to conduct repairs.

Hospitals in wealthier countries typically purchase modern equipment with a warranty and service contract. There are several reasons that this is unattainable or even inapplicable to an LIC setting. The cost for new ultrasound equipment ranges from $10,000 for a non-Doppler laptop system with a single probe to $150,000 for a multi-probe console full-capability system. Many facilities and charities cannot afford new equipment and likewise cannot tolerate the multiple-year delay to raise funding. Furthermore, getting a warranty serviced in LIC can be difficult or impossible due to lack of parts and bioengineers.

## Experiences and strategies building ultrasound capacity

Building radiology capacity in LIC often requires sourcing the imaging equipment and finding ways to service that equipment for the client site. We propose several strategies that have been useful to our organization to achieve these goals.

### *Building relationships*

Building relationships with hospitals fosters the ability to understand complex situations and the true nature of the problems they face. Having experienced radiologists tour the facilities and make assessments ensures that the problems, potential solutions, and obstacles are correctly identified from the beginning, given the firsthand nature of observation and project engagement. It has also been our experience that clients may be more receptive to building new partnerships when senior members are involved from first contact. Likewise, building equipment vendor relationships is key to success, and networking is often necessary to build a resource base. This can be accomplished by going to scientific conventions such as the Radiological Society of North America (RSNA) to meet with vendors and explore potential working partnerships. Charities can build their credibility by completing real-world projects to establish their reputation and integrity which, in addition to having operational transparency, can help build vendor relationships. HRD Corps has had success with several vendors using these methods, including receiving discounts on equipment pricing, equipment assessment, and equipment storage. Additionally, networking with other charitable groups that are involved with hospitals can also be helpful and may be mutually beneficial.

**Figure 1. Sample of receipt of donation form.**

Jane Doe
President, Radiology Charity
janedoe@email.com
1-234-567-8900

Charity Logo

***Receipt of Donation***

To Whom It May Concern:

The <Your Radiology Charity Name> is a USA 501c3 Tax Exempt Charitable medical organization based in <Your City, Your State> which has donated the following equipment without receiving any payment or compensation. The equipment is donated in 'as is' condition without warranty.

**Item**

Description: Portable Medical Ultrasound

Manufacturer & Model: Acme Model #1000

Serial Number: #XYZ1234

Condition: Refurbished

**Recipient**

Name: Dr. William Osler

Title: Chief Medical Officer

Facility: St Elsewhere Hospital

Location: Port-au-Prince, Haiti

Recipient Signature: _____

Date: _____

**Figure 2. Sequoia 512 c model ultrasound machine.**

### *Acquiring 501(c)(3)status*

All businesses in the United States must pay taxes. However, if an organization can prove they have a charitable mission, they can apply to the government for an exemption from paying taxes. The part of the USA tax code that regulates charities is section 501(c)(3). Organizations that are granted charitable status often refer to themselves as a non-profit or a "501(c)(3)." American citizens must also pay taxes on the money they earn, but if a citizen or company donates to a 501(c)(3) charity, they can deduct the donation amount from their taxes. In the USA, this makes donation beneficial to both the charity organization and the donor. Both the donor and the charity organization must keep precise records or risk prosecution from the USA government for tax evasion. Figure 1 shows an example of a donation receipt. All 501(c)(3) organizations must file a federal tax report every year detailing all the money and equipment that entered and left the organization. Achieving 501(c)(3) tax exempt status is an important milestone for a charity organization. It garners credibility in the eyes of equipment vendors and clients alike, as well as offering legitimate tax savings for the donors when they give money.

Because the 501(c)(3) regulations require the charity to have four governing officers, HRD Corps has selected a president, vice-president, secretary, and treasurer. However, operationally, we are each equal directors working on projects for our clients. Part of the 501(c)(3) application requires the charity to register as a corporation in a state within the USA. Each state has different requirements for corporate governance, bylaws, and documentation. HRD Corps has incorporated in the state of Arizona and follows their bylaws codifying the basic tenets of legal behavior and governing decorum. The state requires one official meeting per year, although we have extensive internal communication.

HRD Corps has received significant corporate support in the form of donations of equipment and has had modest success thus far in receiving corporate or individual financial donations.

### *Working with a single model*

Working with a single model of any imaging modality allows for simplicity of implementation. For example, we currently only support the Acuson/Siemens Sequoia ultrasound for our clients (Figure 2).

Having a limited number of ultrasound models also reduces the burden of engineer staffing needs, as engineers often only have expertise on specific models. Models should be chosen based on their reputation for reliability and the number of installed machines, which impacts the supply chain for parts and acquisition cost. A model that was highly successful in the marketplace will usually have many machines available in the refurbishment market and a better supply of replacement parts. Of note, one advantage of older models is that they may not require an annual license renewal, which is now commonplace with newer computerized imaging equipment.

**Figure 3a. Sequoia ultrasound machine is palletized for secure shipping.**

**Figure 3b. Ad hoc delivery of a donated ultrasound machine to Hôpital d l'Universite d'Etat d'Haiti (HUEH) in Port-au-Prince.**



HRD Corps has developed a relationship with a vendor that refurbishes and donates Sequoia ultrasound machines for charitable purposes. Currently, all Sequoias are refurbished and sourced from this trusted vendor which covers the cost of refurbishment. The Sequoia was a popular ultrasound model with over 150,000 sold. The last one was built in 2008. Sequoias are console-sized machines with full capability to perform all exam types, from transvaginal to cardiac and grayscale to color Doppler. Over the last three years HRD Corps has deployed 22 Sequoia systems into Haiti (Figures 3a and 3b).

### *Equipment redundancy*

To help prevent clinical services from faltering if the provided equipment becomes nonfunctional, HRD Corps has made the general policy of donating one extra ultrasound machine to create on-site redundancy. We have coined this the "N+1 rule," where N is the number of ultrasound machines a program needs based on our assessment. For example, if a hospital needs three US machines, four are donated so there is a spare machine already on-site and ready to use if any of the machines become inoperative. This allows the client site to remain fully functional while the machine is repaired. The "N+1 rule" also applies to equipment parts. For example, since the Sequoia hard drives often fail, these machines are deployed with pre-programmed spare hard drives that are stowed inside their cabinets and ready for installation.

### *Using refurbished equipment*

Acquisition costs of equipment can impact building radiology capacity, and it is tempting to purchase new, state-of-the-art equipment. There are several reasons why a refurbished Sequoia is a more practical solution in LIC. Table 1 illustrates the major differences in acquisition costs between a donated refurbished Sequoia 512c model and a new Sonoscape S2 laptop ultrasound (Figure 4).

The Sonoscape S2 laptop model costs $10,900 with a charity discount, whereas the capital cost to HRD Corps for a refurbished Sequoia is $0 through a charitable vendor. Removing capital expense from a project by obtaining donated equipment allows reallocation of substantial resources for training and maintenance. The warranty for a new Sonoscape is two years, which is included in the purchase price of $10,900. However, the true cost of honoring a warranty is underestimated as it often requires transporting the equipment back to the United States given the lack of local bioengineers and parts in Haiti. Total cost over one year, including acquisition cost, warranty, delivery, and installation, is approximately $13,000 for the Sonoscape versus $1,389 for the refurbished Sequoia US machine.

The refurbished Sequoias are also equipped with more probes than the Sonoscape. An additional benefit of the larger ultrasound model is that it is a theft deterrent, too heavy to be stolen, which unfortunately is a real consideration according to our clients. The ultimate lesson is that a reliable, functional older machine that has a higher benefit-cost ratio in an LIC is usually better than a newer, more expensive machine that may not offer any better functionality.

### *Repair and service record*

The most important challenge of sustaining imaging equipment in the LIC setting is obtaining reliable service.

**Table 1. Cost comparison between a new portable Sonoscape S2 laptop ultrasound and a larger refurbished Sequoia 512c ultrasound model.**

| | New Sonoscape S2 | Refurbished Sequoia 512c |
|---|---|---|
| Acquisition cost | $10,900 (charity discounted) | Free |
| Warranty | 2 years parts and labor | Free refurbished parts when available |
| Delivery | Typical commercial flight from East Coast USA to Port-au-Prince (as carry-on baggage)<br>Approximately = $1,000 | Domestic & international transport via private shipping from East Coast USA to Port-au-Prince<br>Approximately = $1,000 |
| Probes | Two | Seven |
| Color Doppler | Yes | Yes |
| Theft mitigation | Sonoscape mounted to console sized steel cart.<br>Charity discount = $950 | Not an issue due to bulky size and heavy weight |
| Uninterruptible Power Supply (Backup Battery) | $150 | $389 |
| First year costs | Probe damaged within first year was covered under warranty | $0 |
| Total cost in one year | $13,000 | $1,389 |

**Table 2. Sequoia deployment and repair history at various sites in Haiti and current functional status of each ultrasound machine.**

| Number of machines donated to site | Location | Deployment date | Repair | Status |
|---|---|---|---|---|
| 1 | HUEH | May 2017 | New hard drive<br>New keyboard | Functional |
| 2 | HUEH | Dec 2019 | | Functional |
| 1 | St. Luke | Mar 2018 | Reloaded hard drive | Functional |
| 1 | St. Damien | Mar 2018 | | Functional |
| 1 | Chancerelle | Mar 2018 | Needs circuit board | Broken |
| 2 | Chancerelle | Dec 2019 | | Functional |
| 2 | St. Francois | Sept 2017 | | Functional |
| 5 | GHESKIO | Nov 2018 | | Functional |
| 1 | Caracol | Mar 2018 | | Functional |
| 1 | OFATMA | Mar 2018 | | Unknown |
| 2 | Justinien | Oct 2019 | | Functional |
| 1 | La Paix | Oct 2019 | | Functional |
| 1 | La Paix | Dec 2019 | | Functional |
| 1 | Port de Paix | Oct 2019 | | Functional |

There are only a few trained repair and maintenance engineers in Haiti, leading to unused broken equipment that is sometimes discarded, even for minor repair needs. Therefore, building a network of engineers who specialize in the type of equipment becomes important (Figure 5). The most practical way to service an ultrasound machine may be to bring it back to the United States for repair and then have hospital or charity personnel return it to the client country. The process of transport to and from the USA, plus repair time, typically takes 6-12 months. To make matters more complicated, some warranties are void if the machine is taken out of the USA.

In our experience, taking cell phone photographs of the error codes on the US screen usually allows an off-site engineer to diagnose or narrow down the problem to a few causes. If a Sequoia cannot be repaired, it is kept on location so its parts can be harvested to keep the other Sequoias operational.

HRD Corps has thus far successfully made three field repairs (Table 2) to machines located at the University Hospital, also known as Hôpital d l'Universite d'Etat d'Haiti (HUEH), St. Luke Hospital, and Chancerelle Hospital.

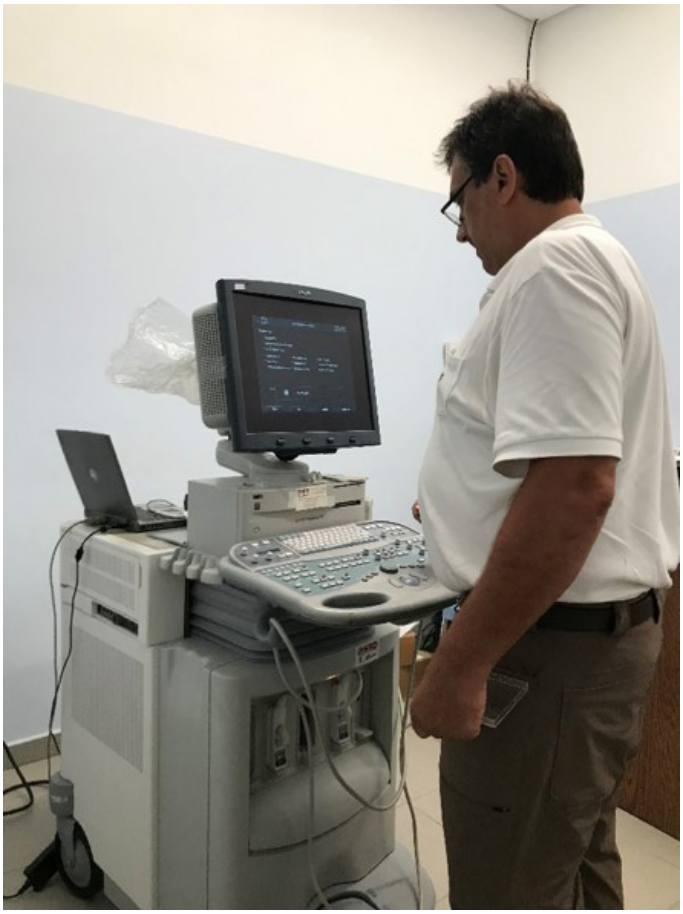
Thus far, hard drives had to be repaired twice and a keyboard user interface had to be replaced once. In the case of one Sequoia, the problem could not be diagnosed remotely from the United States and its broken circuit board has yet to be replaced, requiring an engineer to return with parts. Two UPS batteries have broken after a relatively short average lifespan of 2 years, which perhaps speaks to the frequency of power outages and the constant variation in voltage experienced in Haiti. The remaining ultrasound machines at other sites are functional to the best of our knowledge, except the OFATMA (Office d'Assurance Accidents du Travail, Maladie et Maternité) site in which the state of the donated US is unknown to us, as it was the only machine donated to the government sector.

### *Impact of the donation program*

Building ultrasound capacity has a significant impact on patient care as well as education. The HRD Corps assessment tours showed there was tremendous need for more ultrasound capacity at all sites that were visited. We have instituted a data collection process at our donation sites, although it is often hampered by frequent labor strikes, political demonstrations, and changes in staff. Pre-donation data, including number and types of US, was commonly not available from sites that already had functioning US equipment. Three sites that received Sequoia donations did not have any US equipment before the donations (Port de Paix, Chancerelle, and Caracol). Chancerelle is the main public obstetrical hospital of Port-au-Prince. They had no functioning US equipment before the Sequoia donation. Our data from May 2020, after the donation, showed that 77 obstetric and pelvic ultrasounds were performed, none of which could have been performed without the Sequoia. HRD Corps has continued efforts to collect US usage data despite the COVID-19 pandemic. Many of our clients have given feedback that the Sequoia donation program has

**Figure 4. New Sonoscape S2 laptop ultrasound machine.**


**Figure 5. American ultrasound bioengineer repairing a donated refurbished Sequoia hard drive at St. Luke hospital in Port-au-Prince.**



dramatically improved patient care by directly increasing the number of studies performed, increasing the scope of services, and improving access for patients. None of the ultrasounds are being used routinely for interventional procedures, although this will hopefully change as the Haitian healthcare infrastructure improves.

At HUEH, the only radiology residency training program in Haiti, the most recent monthly data showed 73 ultrasound exams were performed with the donated Sequoias. The radiology residents indicate ultrasound cases have significantly increased due to the donations, however, no pre-donation volume data is available for comparison. Most of the ultrasound exams were obstetrical, female pelvis, and abdominal exams. The educational impact of the Sequoia donation at HUEH is further described by a former Haitian radiology resident who trained at HUEH:

"Before the first Sequoia was donated to HUEH in May 2017, the radiology department had a single Sonosite Titan laptop style ultrasound machine, which was probably built in the mid 2000s. It had only one functional curvilinear probe that could perform basic abdominal and pelvic studies. After the Sequoia donation, we were able to do endovaginal, vascular, and small parts exams, improving patient care as well as resident education. When only one functional machine was available within the department, ultrasound rotations were predominately reserved for senior residents to hone their skills before graduation. The added ultrasound capacity of the Sequoia donation has allowed junior residents to start ultrasound training earlier, which over time resulted in longer training times and better experience for the residents" (Yamile Blain, personal communication, 2019).

## Conclusion

Haiti is one of the poorest countries in the world and its healthcare system is in a grave state. HRD Corps is a small 501(c)(3) tax exempt USA charity that has had success in garnering donated refurbished equipment for deployment to poor regions of the world. Building radiology capacity can help healthcare providers in LIC diagnose and manage disease. Ultrasound is less expensive than other cross-sectional imaging modalities such as CT and MRI, making it an attractive option for donation by charitable organizations. Radiology capacity and education in Haiti has increased through the donation of 22 refurbished Sequoia ultrasound machines. Donating redundant equipment through the "N+1 rule" and deploying the equipment pre-packaged with replacement parts has contributed to robust clinical services. Further research would include analyzing the impact of the donated equipment and how it translates to better patient care. Future directions include technologist training on the donated ultrasound machines, which is currently underway by our organization, and expanding this program to our other client sites in Central America and Africa.

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## Conflicts of interest

The authors report no conflicts of interest.

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