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# Deploying Portable Ultrasonography with Remote Assistance for Isolated Physicians in Africa: Lessons from a Pilot Study in Mali

**Cheick Oumar Bagayoko[a,b,c], Mahamoudane Niang[c], Seydou T Traoré[c], Georges Bediang[a], Jean-Marc Naef[a], Antoine Geissbuhler[a]**

[a] *Department Radiology and Medical informatics, University Hospitals of Geneva, Switzerland*
[b] *Department of Public Health and Specialities, Medical School, University of Bamako, Mali*
[c] *Centre d'Expertise et de Recherche en Télémédecine et E-santé, Hôpital Mère Enfant, Bamako, Mali*

**Abstract**

*Objective : demonstrate the feasibility of deploying portable ultrasonography with remote assistance to improve the diagnostic capabilities of isolated physicians in Africa. Methods : the approach is based on the training of general practitioners for the use of ultrasonography, and the remote support by radiologists using dedicated tools for image transfer over low-bandwidth internet connections. Results : our early results in a pilot project in Mali show that this approach is feasible, and that isolated physicians can productively use ultrasonography to improve diagnosis and management decisions such as the need for a medical evacuation towards a reference hospital. Conclusion : these encouraging early results must be confirmed by larger-scale studies, in order to better understand the organizational requirements and demonstrate outcomes and return on investments for such telemedicine services. This scale-up project will start in 2010 in collaboration with the International Development Research Center of Canada.*

***Keywords:***

Telemedicine, Teleexpertise, Teleradiology, Ultrasonography, Africa

## Introduction

The usefulness of ultrasonography for improving diagnosis and patient management in rural Africa has been demonstrated by several studies [1-4], in particular for obstetrical and abdominal pathologies.

The possibility to train non-radiologists to the use of ultrasonography for emergency situations [5] and for obstetrical evaluation [6] has also been established. Such training requires significant efforts for initial and continuing education, as well as monitoring by radiologists.

However, such specialists are rarely found outside of capital cities in Africa. For example, there is only one radiologist outside of Bamako in Mali, a country of 2'421'000 square kilometers with a population of 14 millions. Projects have therefore been developed in order to provide a remote support by radiologists, to improve the quality of the service and to support isolated care professionals facing challenging cases.

In addition, projects enabling the remote control of ultrasound imaging have been developed, such as the TERESA project [7] of the University of Tours in collaboration with the European Spatial Agency.

As portable ultrasonographs are becoming cheaper and connectivity of isolated hospitals is improving, it becomes realistic to deploy such tools in remote areas, but there are still many questions related to the training of the professionals, the organization of the remote support, the usability of telemedicine software, and the effective use of usually poor internet infrastructures.

In this study, we investigate the feasibility of deploying portable ultrasound imaging devices in remote hospitals, with distance assistance, through low-bandwidth connections with national reference hospitals. The pilot site is a rural hospital in Mali, the reference hospital being based in Bamako, the capital, 875 kilometers away.

We use the infrastructure and organization deployed by the RAFT (Réseau en Afrique Francophone pour la Télémédecine), which provides connectivity to dozens of hospitals in French-speaking Sub-Saharan Africa [8,9] in order to support continuing medical education and tele-expertise for isolated physicians and care professionals. We also make use of the CERTES, center for expertise in telemedicine in Bamako, which provides services to telemedicine users in Mali, and more generally in the West African region [10].

## Materials and Methods

### Materials

The ultrasound imaging device is the Voyager® Compact Imaging Device [11] (Ardent Sound Inc., Meza AZ, USA) equipped with two probes (4 and 10 MHz) and powered by an external battery. It is connected to a standard laptop computer via a USB cable. The imaging software, Ardent Examiner®, runs on the laptop and produces DICOM images which can be exported.

An additional software, Medbook©, has been developed within the scope of this project in order to receive these DICOM images, compress them and securely transmit them on a distant server where they can be retrieved for review by experts. The goal of this software is to be able to rapidly transmit these images over a low-bandwidth internet connection of 30-40 kilobits/second, the bandwidth that can currently be obtained on the cheap DSL or mini-VSAT connections deployed in the RAFT network. It contains a DICOM listener based on the open-source dcm4che platform [12], and uses the Theora [13] open-source video compression. It can produce various images at different compression levels (Figure 1.) thus enabling very high-level of lossy compression, as well as lower-, lossless compressions for specific images. This is particularly useful in order to define imaging and image transmission protocols that take into account the actual possibilities of the existing connections. Medbook© also helps collecting structured information to be sent to the expert, as well as an identity management tool to label cases.

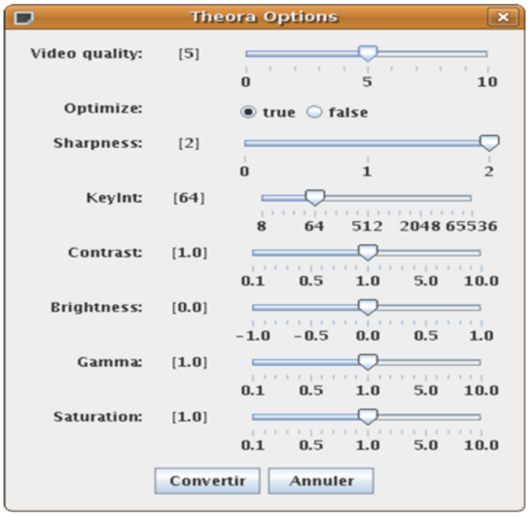


*Figure 1 - Medbook interface screenshot: Theora options for defining and testing various compression levels*

## Methods

### *The RAFT network*

Continuing education of healthcare professionals and access to specialized advice are keys for the quality and efficiency of a health system. In developing countries, these activities are usually limited to capitals, and delocalized professionals do not have access to such opportunities, or even to didactic material adapted to their needs. This limits the interest of such professionals to remain active in the periphery, where they are most needed to implement effective strategies for prevention and first-line healthcare.

In order to address these needs, the Geneva University Hospitals have developed a telemedicine network in Africa (the RAFT, Réseau en Afrique Francophone pour la Télémédecine), first in Mali, then in Mauritania, Morocco, Cameroon, and, since 2004, in Burkina-Faso, Senegal, Tunisia, Ivory Coast, Madagascar, Niger, Burundi, Congo-Brazzaville, Algeria, Chad, and Benin.

The core activity of the RAFT is the webcasting of interactive courses targeted to physicians and other care professionals, the topics being proposed by the partners of the network. Courses are webcast every week, freely available, and followed by hundreds of professionals who can interact directly with the teacher. 70% of these courses are now produced and webcast by experts in Africa. A bandwidth of 30 kbits/second, the speed of an analog modem, is sufficient, and enables the participation from remote hospitals or even cybercafés.

Other activities of the RAFT network include teleconsultations, and collaborative development of educational on-line material.

The network is currently organized and run by more than 30 national coordinators and a small coordination team based in Geneva. In each of the partner countries, the RAFT activities are supervised by the focal point, a medical authority (usually a university professor) that links the project to the national governmental bodies (ministry of health, ministry of education). A local medical coordinator (a junior physician) and a technical coordinator take care of the day-to-day operations, including communication with the care professionals, identification of training needs, technical training and support of the various sites within the country

### *Pilot site*

The pilot site is the rural hospital of Dimmbal, in the Dogon country in the north of Mali, 875 kilometers away from Bamako, where the radiological expertise resides. Before being connected to the RAFT network, Dimmbal was quite isolated, the first telephone 15 kilometers away, and the first internet connection 120 kilometers away. The hospital, serving a population of about 30'000, and staffed with a physician, a nurse and a midwife, was equipped with a mini-VSAT satellite connection in 2004 (Figure 2.), and has served as a laboratory for the RAFT network to investigate the feasibility of deploying distance-education, telemedicine and de-isolation activities for care professionals in rural Sub-Saharan Africa [14].

*Figure 2 - Dimmbal rural hospital, in the Dogon country (Mali), equipped with a mini-VSAT internet connection*

***Reference hospital***

The reference hospital is the Hôpital Mère-Enfant "Le Luxembourg", one of the three main reference hospitals in Bamako, capital of Mali. This hospital hosts the CERTES, center for expertise, education and research in telemedicine. Amongst others, CERTES provides basic computer and internet skills courses, as well as specific courses for the use of distance education and telemedicine tools.

***Computer and internet skills development***

This is an essential phase as many care professionals still have limited computer and internet usage skills. Although the current physician of the Dimmbal hospital has acquired these skills through previous training courses, any deployment of such tools must be accompanied by such basic training, as the internet connectivity will be the umbilical link between the remote hospital and the centers for expertise, whether medical or technical. These skills are usually acquired through a one-week course, either in the CERTES in Bamako, or at decentralized workshops in regional cities where 10-15 care professionals are regrouped.

Additional skills for the specific usage of the ultrasound device and the image transfer systems are also needed.

***Ultrasound imaging training***

Basic training for the proper usage of the ultrasound imaging device requires approximately one month of practice with a trained radiologist. The duration of the training depends in part on the availability of appropriate cases. The goal is to develop the basic skills and make sure that the trainee will be able to reproduce the main, key images that are used for the evaluation of patients.

***Organization of the tele-expertise service***

Once trained with the basic skills for acquiring and interpreting ultrasonographic images the trainee is also taught how to decide when to seek expert advice for the analysis of an image or a video sequence.

At CERTES, a center of expertise is setup and physicians receive tele-expertise requests and route these to the appropriate specialists.

Ultrasound images, first acquired in a DICOM format, must be exported and compressed using Medbook©, then uploaded on a secure server where the specialists can access them for review. The requesting physician is then informed directly by the expert through the teleconsultation platform.

## Results and lessons learned

***A case-report from the Dimmbal pilot site***

A 22-year old woman, at the seventh month of pregnancy, consults the Dimmbal hospital for musculoskeletal and abdominal pain. Anamnesis reveals that she has been battered by her husband. Physical examination shows multiple contusions. The ultrasound examination (Figures 3 and 4), reviewed in near real-time by the radiologist in Bamako, confirms that the fetus is not showing signs of suffering. The patient is therefore kept for observation at the Dimmbal hospital, and not evacuated to the regional hospital.

***Image compression and image quality for diagnosis***

One of the key limiting factors for this application is the bandwidth. It is unlikely that a remote hospital will be able to afford more than a basic internet connection, given the high cost of these outside the main cities. Currently, a reasonable bandwidth is about 200 kilobits per second for downloads, and 30-40 kilobits per second for upload.

For this tele-ultrasonography scenario, the uplink is critical, as images are sent from the periphery to the center of expertise. A video sequence of 150 frames (10 seconds), uncompressed, in DICOM format, weighs 170 megabytes. A frame-by-frame compression in JPEG 2000 will reduce it to 5.4 megabytes, whereas a Theora video compression will reduce it to 1.4 megabytes, with an output quality judged sufficient for diagnosis by several radiologists who participated in these experiments. With such compression rates, it is possible to send such video sequences in 4 to 5 minutes over a 40-kilobits per second uplink. This obviously requires a careful selection of the video sequences by the requesting physician.

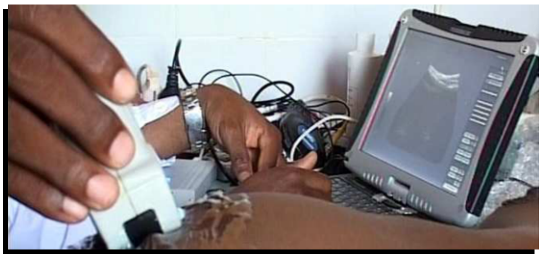

*Figure 3 - Portable ultrasonography setup. The same computer is used for acquiring the images, and then transmitting them, compressed, to the reference center*

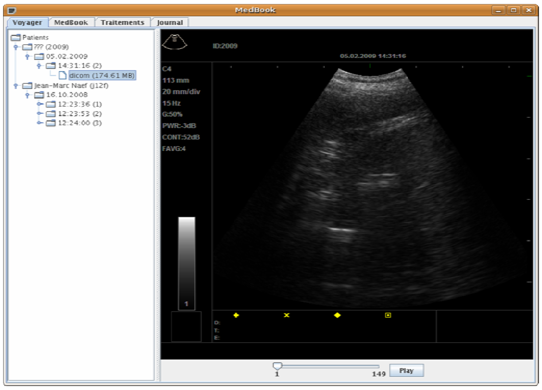

*Figure 4 - Medbook screenshot: selection, compression and transmission of an ultrasonography video sequence*

***Localization of these activities within the health system***

Although we piloted the tool in a rural hospital, it appears that the level of activity is not sufficient to justify such investments, and we are now moving to the first level of reference, i.e., district hospitals, where the number of cases is higher, and where the overall infrastructure of the hospital is sufficient to take care of many of the patients evaluated with this telemedicine service, thus improving the value of the ultrasound imaging for deciding whether or not to evacuate the patient to the next level, i.e., the regional hospital.

The same remark pertains to the sustainability of financing the internet connection, which is very difficult to achieve at the rural level.

**Delegation of the ultrasound imaging to other care professionals**

There are good arguments, and needs, to train non-physicians for the use of ultrasound imaging, in particular for midwives performing obstetrical evaluations. It is however important that these professionals don't replace specialists and that they respect the ethical and deontological rules for reference of patients. An easily accessible link to specialists has the potential to maintain a balanced distribution of roles and facilitate quality monitoring and continuing education of these care professionals.

***Availability of timely expert advice***

A critical success factor is the ability to access expert advice in near to real-time. If the delay is too long, or the expertise insufficient, then the requesting care professional will not bother trying to access it.

The experience of the CERTES, in Bamako, shows that this can be achieved through a properly-staffed operational center. Obviously, such a center can only be maintained if there is a high-enough level of activity, which can be challenging initially.

## Conclusion

This pilot study demonstrates the feasibility of deploying portable ultrasound imaging in remote hospitals and providing timely access to expert advice for difficult cases. The success relies on the proper training of the users, the rigorous organization of the call center and the use of an adapted software for the secure transmission of the images over low-bandwidth connections.

This service complements other services already deployed to help de-isolating care professionals who work in remote areas [8,9], thus creating a critical mass of added value that can justify the investments and maintenance of telemedicine tools in district hospitals.

Although technical evaluations and anecdotal evidences are confirming the potential of these tools to strengthen health systems, it is now important to demonstrate patient outcome improvements and measure financial returns on investments, as these stronger evidences are necessary to drive the further development and deployment of such systems.

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**Address for correspondence**

Dr. Cheick Oumar Bagayoko
Division of Medical Informatics
University Hospitals of Geneva
Rue Gabrielle-Perret-Gentil 4
1211 Geneva 14
Switzerland
E-mail: cheick-oumar.bagayoko@hcuge.ch