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Proof of Concept of the Contribution of Tele-auscultation in the Screening of Heart Disease: A Cross Sectional Study

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Background and purpose: Cardiovascular diseases are the leading cause of death worldwide, accounting for 31% of all deaths in 2016. Echocardiography is the reference screening tool, but its widespread use in developing countries is limited by its high cost. The objective of this study was to evaluate auscultation of heart sounds using an electronic stethoscope coupled with tele-transmission and remote interpretation by a distant physician as a less expensive alternative.
Methods: This was a descriptive cross-sectional study. Participants meeting inclusion criteria were examined face-to-face by a cardiologist (A) using a traditional stethoscope and following a well-defined protocol. Heart sounds were then recorded by a health professional using an electronic stethoscope. A part of these digital auscultation records were randomly selected and evaluated by cardiologist (A) and remotely (via a telemedicine platform) by cardiologist (B), then rated as normal or abnormal. Diagnostic findings of cardiologists A (digital-based) and cardiologist B (remote) were compared to those found by the cardiologist (A) during face-to-face consultation by using the Cohen's Kappa coefficient.
Results: We enrolled 22 patients in the study and ten (n=10) were randomly selected for analysis. The level of agreement between face-to-face and digital-based auscultatory findings by cardiologist A was moderate (K = 0.583). It was satisfactory (K= 0.615) between face-to-face auscultatory findings by cardiologist A and tele-auscultation findings by cardiologist B.
Conclusions: This study highlights the potential of using a tele-auscultation system in the assessment of cardiovascular diseases in remote areas (developing countries) where there is a shortage of qualified personnel.

Keywords: Telemedicine, Tele-auscultation, Screening, Heart disease, Electronic stethoscope

1 Introduction

Cardiovascular diseases are the leading causes of death worldwide, accounting for 31% of all deaths in 2016 [1]. Their high mortality rates (17.9 million deaths per year) and morbidity, particularly cardiac, are associated with high levels of disability and loss of productivity, exacerbating poverty and increasing health inequalities [2–5]. Reducing the impact of these diseases requires not only better care for known patients, but also early diagnosis of patients who ignore their condition [6,7].

Screening is of public health interest for these diseases because it reduces the associated burden. In resource-limited countries, due to the lack of infrastructure, qualified personnel, and financial resources, it is difficult for this screening to be based on the use of reference diagnostic tests such as echocardiography [4–8].

In such contexts, the practice of clinical auscultation remains the most frequently used alternative. It is a low-cost, non-invasive diagnostic technique that derives its effectiveness from the usual association between the sounds emitted by the heart, including when it is in good health, and the underlying clinical lesions [9,10]. Auscultation could, therefore, be considered as a tool for early detection of heart disease [10,11].

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In addition, with the help of an electronic stethoscope that allows recordings even by a junior doctor, well-conducted auscultation coupled with the remote transmission of these recordings to a cardiologist would be an alternative. This application of telemedicine in auscultation (tele-auscultation) has many advantages in terms of effectiveness and efficiency [8]. This makes it possible to reduce the cost of diagnosis and patient follow-up, even in remote areas, while maintaining similar efficiency of the conventional face-to-face auscultation [13–15].

However, the effective implementation of such a remote monitoring system capable of providing assistance for diagnosis (through remote experts) and patient follow-up requires validation before being deployed for screening purposes. To date, there are few studies [13–16] conducted in developing countries in general, and in African countries in particular, on the possibilities offered by tele-auscultation. This study was conducted in order to implement such a remote monitoring system for the screening of heart disease.

The objective of this study is to evaluate the relevance of a remote auscultation monitoring system for its possible use in the screening of heart disease in a resource-limited country such as Cameroon.

2 Materials and methods

2.1 Design, period and setting

This was a descriptive cross-sectional study (fig. 1), which was done at the outpatient cardiology unit of the Yaoundé Central Hospital over one month (April 2017). Participants who met the inclusion criteria (22 cases) and gave their informed consent were examined (face-to-face cardiac auscultation) by a cardiologist (cardiologist A) using a traditional (non-electronic) stethoscope and following a well-defined protocol. These participants were auscultated a second time and their respective heart sounds were recorded by a health professional (non-specialist) using an electronic stethoscope. Subsequently, the recordings of some of these participants (10 cases) were randomly selected. These digital recordings were listened to and evaluated by cardiologist A and then sent to a second remote cardiologist (cardiologist B) via a telemedicine platform. The diagnostic conclusions of face-to-face auscultation and those from digital-based and remote auscultation (Cardiologist A and Cardiologist B respectively) were compared. The degree of intra and inter-rater agreement were estimated using Cohen's Kappa coefficient.

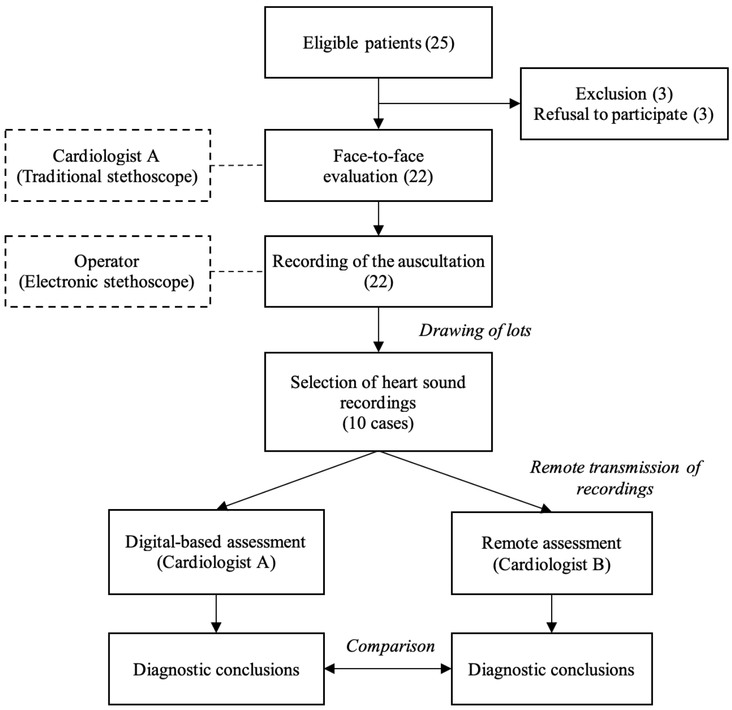

Figure 1: Design of the study

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2.2 Participants

All participants aged 21 years and above who came for a consultation in the cardiology outpatient department at the Central Hospital of Yaoundé, who did not have known heart disease and agreed to participate in the study were included. Participants whose audio recordings of the cardiac auscultation were of poor quality were excluded.

2.3 Sample and case description

Sampling was consecutive. Of the 25 patients who were eligible, twenty-two (22) adult patients were selected for the face-to-face cardiac auscultation phase, we had 11 patients with normal auscultation and 11 patients with auscultation abnormalities. Subsequently, 10 cases were randomly selected (by drawing lots) for digital-based and remote assessments by two cardiologists. The average age of the patients randomly selected was 47.3 years. Sixty (60) percent of the participants were of the male sex. The most common pathology found was high blood pressure (90%).

2.4 Selection of evaluators (judges)

Two evaluators (judges) were selected on the basis of their comparable experience in the medical field in general and in cardiology in particular. Cardiologist A has nine years of experience in the medical field, including eight years in cardiology. Cardiologist B has 11 years of experience in the medical field, including eight years in cardiology.

2.5 Procedure

Face-to-face evaluation and recording by an operator.
The twenty-two (22) patients selected were examined (cardiac auscultation) by a cardiologist (cardiologist A). This examination was done in person using a traditional stethoscope (non-electronic 3M Littmann® 2 178 Master brand). Five (5) cardiac areas (aortic, pulmonary, Erb, tricuspid and mitral) were systematically auscultated in all patients in the seated position. At the end of each auscultation, cardiologist A had to interpret and provide a diagnostic conclusion: either the auscultation was normal or abnormal. Using the same auscultation protocol, these patients were subsequently examined by a health professional (non-specialist) using an electronic stethoscope. The digital audio files obtained as a result of these tests were recorded on a computer.

Drawing of lots.
Patients were divided into 2 groups. The first group included patients whose cardiologist A's diagnostic conclusion at the end of the auscultation was normal, while the second group included patients whose diagnostic conclusion was abnormal. In each group, each patient received an identifier based on an alphanumeric code ranging from 1 to 11, which was associated with the letter "N" for patients with normal auscultations and "A" for patients with abnormal auscultations. Each code was written on paper and placed in two different ballot boxes. A person independent of the research team was invited to randomly draw 10 patients: 6 patients in the box containing patients with abnormal auscultations and 4 patients in the box containing patients with normal auscultations.

Digital-based and remote assessment of heart sound recordings.
Two weeks later, the recordings of the patients whose numbers were drawn at random were listened to by cardiologist A from a computer (digital-based assessment). At the end of this assessment, he had to conclude by stating if the examination was normal or abnormal. Subsequently, these recordings were transmitted for interpretation to another cardiologist (cardiologist B) remotely (remote assessment) via the Bogou telemedicine platform[17] (the telemedicine platform developed by the "Réseau en Afrique Francophone pour la Télémédecine") [18]. Cardiologist B interpreted these recordings, without knowing the diagnostic conclusions of cardiologist A. At the end of his assessment, cardiologist B was required to provide a diagnostic conclusion: either the auscultation is normal or abnormal.

Concordance between face-to-face, digital-based and remote assessments.

Table 1: Interpretation of the Kappa coefficient

Value	Degree of agreement
<0	Strong disagreement
0.00—0.20	Very poor agreement
0.21—0.40	Low agreement
0.41—0.60	Average agreement
0.61—0.80	Satisfactory agreement
0.81—1.00	Excellent agreement

The diagnostic conclusions from the face-to-face auscultation of cardiologist A were compared with those from the digital-based auscultation of cardiologist A (intra-rater agreement). The same applies to the face-to-face auscultation of cardiologist A and those from the remote auscultation of cardiologist B (inter-rater agreement). The degrees of intra and inter-rater agreement were thus assessed using Cohen's Kappa coefficient (Table 1) [19].

2.6 Data collection

The clinical diagnostic findings of each cardiologist were recorded on a specially designed data sheet.

2.7 Outcomes

The main outcomes were (i) the presence or absence of abnormalities on auscultation and (ii) the degrees of agreement within (intra-rater) and between (inter-rater) evaluators.

2.8 Data analysis

Data were entered using Epidata v.3.1 software and analysed using IBM-SPSS v.20 software for Windows. The categorical variables were represented by frequencies and percentages. The continuous variables were represented by their mean and standard deviation.

3 Results

3.1 Sociodemographic profile of participants and diagnostic conclusions (cardiologist A)

In total, cardiac auscultations of 22 patients were performed by cardiologist A (Table 2).

Table 2: Socio-demographic profile of participants

Variable		n (22)	Frequency (%)
Gender	Male	11	50
	Female	11	50
Profession of the participants	Retired	9	40.9
	Private (informal)	7	31.8
	Private (formal)	4	18.2
	Public	2	9.1
Main complain	HBP* monitoring	15	68.2
	Dyspnea	3	13.6
	Edema	3	13.6
	Other	1	4.5
Cardiac Auscultation	Normal**	11	50
	Abnormal***	11	50

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Age (years)			Mean (SD)
			55.36 (15 683)

**High Blood Pressure; **Absence of pathological sound; ***Presence of pathological sound*

There were as many men as women. The average age was 55 years. The majority of participants were retired and the main health complaint was about high blood pressure. The most common auscultatory anomaly found was a systolic murmur at the mitral area.

3.2 Diagnostic conclusions and degree of agreement within and between judges

Of the 10 patients randomly selected, cardiologist A's diagnostic findings (face-to-face auscultation) were as follows: 6 patients had abnormal auscultations and 4 had normal auscultations. The anomalies found were essentially: decrease in intensity of the 1st and 2nd heart sounds, mainly in the aortic area; the presence of murmurs most often perceived in systole and audible in the mitral area in 46.1% of cases, in the tricuspid area in 30.8% of cases, and in the aortic area in 23.7% of cases.

Subsequently, the recordings of these patients were re-evaluated (digital-based assessment) by cardiologist A and the diagnostic findings were: 6 patients with normal auscultations and 4 with abnormal auscultations. A comparison of cardiologist A's diagnostic findings (face-to-face cardiac auscultation) with his own findings during the digital-based assessment (interpretation of audio recordings) showed that they were consistent for 3 normal and 5 abnormal auscultations (Table 3). The degree of agreement between these judgments was average (Kappa = 0.583).

Table 3: Intra-rater agreement of judgments (face-to-face versus digital-based assessment)

		Face-to-face auscultation (Cardiologist A)		**Kappa**
		Normal	Abnormal	
Digital-based auscultation (Cardiologist A)	Normal	3	1	0.583
	Abnormal	1	5	

For cardiologist B remote assessment (auscultation), the diagnostic conclusions after evaluation were as follows: 6 normal auscultations and 4 abnormal auscultations. Comparison of the diagnostic findings of cardiologist A (face-to-face cardiac auscultation) and cardiologist B during the remote assessment (tele-auscultation) showed that they were consistent for 4 patients in whom both did not find any abnormalities on auscultation and for 4 others in whom they all found abnormalities (Table 4). The degree of agreement between these judgments was satisfactory (Kappa = 0.615).

Table 4: Inter-rater agreement of judgments (face-to-face versus remote assessment)

		Face-to-face auscultation (Cardiologist A)		**Kappa**
		Normal	Abnormal	
Remote auscultation (Cardiologist B)	**Normal**	4	2	0.615
	Abnormal	0	4	

4 Discussion

Tele-auscultation is a diagnostic method that combines face-to-face auscultation with the use of information and communication technologies to remotely transmit auscultation records for diagnostic purposes or for patient follow-up. It is based on the use of a connected electronic stethoscope.

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Several studies have shown that this approach can be effectively implemented to diagnose heart diseases [15] [20–22].

In our study, the degree of intra-rater agreement between the diagnostic conclusions obtained via face-to-face auscultation and those resulting from digital-based interpretation of heart sound records were average (Kappa = 0.583). This degree of agreement is lower than that of Dahl and al, who found a Kappa of 0.87 [22]. This difference may be due to the fact that in our study, cardiologist A had no clinical information about the participants whose digital heart sound recordings he was evaluating, unlike Dahl and al where the age, symptoms and clinical signs of the patients were associated with the audio recordings. During auscultation, the fact that a physician has access to a patient's clinical information improves decision-making (diagnostic, therapeutic, etc.) [23]. In addition, the electronic stethoscope is a sensitive tool and can perceive sounds that are not perceptible when using a conventional stethoscope.

The degree of inter-rater agreement was based on the comparison between the diagnostic conclusions obtained through the remote analysis of digital heart sound recordings (remote auscultation) by cardiologist B and the face-to-face auscultation by cardiologist A. This degree of agreement was satisfactory (Kappa = 0.615). This level of agreement is similar to that found by Belmont et al who found a Kappa equal to 0.77 although he only evaluated the presence or not of a systolic regurgitation murmur [21]. However, it is lower than that found by Dahl et al. whose Kappa was 0.81 (inter-rater) [15]. These results can be explained by several factors.

First, there is a lack of training and education in tele-auscultation. The introduction of this innovative approach (use of the electronic stethoscope and remote analysis), requires carrying out capacity building sessions beforehand, in order to give doctors all the skills they need to better appropriate the device. In this study, both cardiologists A and B did not receive any prior training sessions on how to listen to digital heart sound recordings. Given the similarities with face-to-face auscultation using a conventional stethoscope, we hypothesised that physicians' appropriation of this digital-based or remote auscultation would be natural and intuitive.

In addition, there are artefacts that may compromise the digital-based or remote analysis of heart sound recordings. Comments were made by the various cardiologists on this subject. Subject to excellent suppression of ambient noise (and therefore better quality of heart sound recordings), a better agreement can be achieved between the conclusions from the face-to-face assessment of patients using the conventional stethoscope and the conclusions from the digital-based or remote assessment (tele-auscultation) of heart sound recordings using the electronic stethoscope [24].

Finally, the residual variability between evaluators can also be explained by the difference in academic background and professional experience between cardiologists [21]. Experienced clinicians will tend to agree strongly when the diagnosis is simple and obvious [21]. However, an agreement between evaluators decreases significantly as the clinical signs to be evaluated become hard to perceive, as this requires the use of personal experience [21]. In this study, the two cardiologists selected had almost the same length of practice in the profession: 9 years for cardiologist A and 11 years for cardiologist B.

5 Conclusion

Although it is not the standard for the diagnosis of cardiac pathologies as it is for cardiac ultrasound, face-to-face auscultation remains the most cost-effective diagnostic method, especially in the context of resource-limited countries. It is a non-invasive and inexpensive diagnostic approach. With the continuous development of information and communication technologies, this face-to-face auscultation can now be done remotely (remote auscultation) through the use of electronic stethoscopes and telemedicine platforms. This study highlighted the possibility of using remote auscultation as a means of assessing patients in a context of limited resources. The degree of agreement between the judgement of the remote cardiologist and that of the face-to-face cardiologist underlines the potential of this method. However, additional studies on a larger scale with a gold standard (cardiac ultrasound) should be considered for better evidences.

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Study Limitations

This study has some limitation: confirmatory cardiac ultrasound was not performed for cases evaluated by cardiologist A during the face-to-face cardiac auscultation. This was not possible because of the high cost of this assessment in our context and the budgetary constraints of our study. To mitigate those limitation, we considered the clinical advice of the cardiologist at the participant's bedside to be close to reality and the audio recordings of the heart sounds were transmitted unchanged to the remote cardiologist using a secure platform.

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Statement on conflicts of interest

The authors declare no competing interest.

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