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Interregional Newborn Hearing Screening via Telehealth in Ghana

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Abstract

Background: Newborn hearing screening is a vital aspect of the Early Hearing Detection and Intervention program, aimed at detecting hearing loss in children for prompt treatment. In Ghana, this kind of pediatric hearing service is available at only one health care facility located in the Greater Accra Region. The current practice in effect has virtually cut-off infants in the other regions from accessing hearing screening and other pediatric audiological services. This has prompted a study into alternative methodologies to expand the reach of such services in Ghana. The present study was designed to assess the feasibility of using telehealth to deliver newborn hearing screening across Ghana.

Purpose: To assess the feasibility of using telehealth to extend newborn hearing screening services across the ten regions of Ghana.

Research Design: A correlational study was designed to determine the extent of association between test results of telehealth and the conventional on-site methods (COMs) for conducting newborn hearing screening. The design also allowed for testing duration between the two methods to be compared.

Study Sample: Fifty infants from the Brong-Ahafo Regional Hospital (BARH) were enrolled. The infants aged between 2 and 90 days were selected through convenience sampling. There were 30 males and 20 females.

Procedure: Newborn hearing screening using distortion product otoacoustic emissions were performed via telehealth. By adopting the synchronous telehealth model, an audiologist located at the Korle-Bu Teaching Hospital conducted real-time hearing screening tests over the internet on infants who were at the BARH. The former and latter hospitals are located in the Greater Accra and the Brong-Ahafo Regions, respectively. As a control, similar hearing screening tests were conducted on the same infants at BARH using the conventional face-to-face on-site hearing screening method.

Data Collection and Analysis: The test results and testing duration of the telehealth method and the conventional on-site approach were compared and subjected to statistical analysis. Here, the Spearman's correlation coefficient (r_s) was used to determine the level of correlation between the test results, whereas the paired *t*-test statistic was used to test the level of significance between the testing duration of the two methods.

Results: Analysis of the test results showed a significantly high positive correlation between the telehealth and the COMs (r_s = 0.778, 0.878, 0.857, 0.823, $p < 0.05$ @ 2.0, 3.0, 4.0, and 5.0 kHz respectively). Also, the difference in testing duration of the two methods was not statistically significant [$t_{(99)}$ = 1.309, $p > 0.05$]. The mean testing duration (in seconds) of telehealth was 27.287 (standard deviation = 27.373) and that of the COM was 24.689 (standard deviation = 27.169).

Conclusion: The study showed the feasibility of establishing an interregional network of newborn hearing screening services across Ghana using telehealth. It is more efficient to deploy telehealth for pediatric hearing services than to have patients travel many hours to the Greater Accra Region for similar services.

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Poor road network, high transportation costs, and bad weather conditions are a few of the reasons for avoiding long distance travel in Ghana.

Key Words: Africa, audiology, Brong-Ahafo Regional Hospital, childhood hearing loss, distortion product otoacoustic emissions, distortion product otoacoustic emissions screening, Ghana, hearing screening, infant hearing screening, Korle-Bu Teaching Hospital, newborn hearing screening, otoacoustic emissions screening, sub-Saharan Africa, synchronous telehealth model, tele-audiology, telehealth, telemedicine

Abbreviations: BARH = Brong-Ahafo Regional Hospital; COM = conventional on-site method; DPOAE = distortion product otoacoustic emissions; KBTH = Korle-Bu Teaching Hospital; OS = operating system; s.d. = standard deviation; THM = telehealth method

BACKGROUND

Childhood hearing loss can lead to speech and language delays, which in effect will affect the children's reading comprehension, cognitive development, socio-emotional functioning, and academic achievements when they grow up (Yoshinaga-Itano et al, 1998; Yoshinaga-Itano, 2004; Moeller et al, 2007). In efforts to address the consequences of hearing loss in children, newborn hearing screening has been established to detect infants at risk of hearing loss for prompt intervention (JCIH, 2007). In the developed countries like the United States, ~95% of infants are screened before they are discharged from the hospital (JCIH, 2007).

Ghana is among a handful of sub-Saharan African countries with established infant hearing screening as part of its Early Hearing Detection and Intervention program. However, because of the lack of hearing health care specialists, especially pediatric audiologists, newborn hearing screening and other infant hearing services are accessible only at the Korle-Bu Teaching Hospital (KBTH) located in the Greater Accra Region of Ghana. The existing practice has left many Ghanaian infants with little or no access to hearing services. This problem has called for alternative strategies to make pediatric audiological services accessible, and telehealth has been considered a viable option.

Telehealth refers to the provision of health care services from one location to another through a telecommunication medium (Krumm, 2010). According to Krumm (2010), audiological services can be delivered through synchronous, asynchronous, and hybrid telehealth models. Synchronous telehealth model uses remote computing, interactive video, and other information and communication technologies to provide real-time audiological services over the internet to patients at distant regions. With asynchronous telehealth model, audiological data are initially recorded at one location and later sent to an audiologist at a distant location. The hybrid model combines both synchronous and asynchronous telehealth models (Krumm, 2010). Information and communication technologies as well as the advent of the internet have provided opportunities for serving communities with limited access to health care, and a number of such studies in audiology abound (Schmiedge, 1997; Givens et al, 2003; Ribera, 2005; Choi et al, 2007; Krumm et al, 2007; Ferrari and Bernardez-Braga, 2009; Ramos et al, 2009; Swanepoel et al, 2010; Penteado et al, 2012).

With Ghana's nationwide coverage for telecommunications, telehealth offers a huge potential for expanding hearing health care services to its ten regional hospitals. Currently, Ghana has a national Wide-Area-Network. There is also an ongoing national program for fiber-optic connectivity for all regional as well as some district hospitals in Ghana (Afari-Kumah and Addo, 2010). These and other advancements in information and communication technologies make it viable to use telehealth to expand pediatric audiological services in Ghana. The present study was designed to assess the feasibility of using telehealth technology to extend newborn hearing screening services across Ghana.

METHOD

Ethical approval (Ref: SAHS-ET./10069343/AA/1A/2012–2013) was obtained from the Ethics and Protocol Review Committee of the University of Ghana School of Biomedical and Allied Health Sciences. The present study was a preliminary tele-audiology research in Ghana using the synchronous telehealth model. The study was conducted between the KBTH located in the Greater Accra Region and the Brong-Ahafo Regional Hospital (BARH) in the Brong-Ahafo Region. These two health care facilities are located 375.0 km apart. KBTH with audiologists who are knowledgeable in pediatric hearing screening served as the host site. BARH served as the remote site in which the infants to be tested in the study were located. Both telehealth and conventional "face-to-face" on-site testing took place at the neonatal intensive care unit block of the remote site. This place was chosen for its quiet environment.

Fifty infants comprising 30 males and 20 females aged between 2 and 90 days were enrolled. Before selection, letters inviting mothers who delivered at BARH for the past 90 days were sent out. Mothers whose infants were on admission at the neonatal intensive care unit were also invited to participate in the study. Sixty-four mothers brought their babies to take part in the study. Using a convenience sampling technique, 50 infants were selected through the assistance of a resident pediatrician and two nurses at BARH. Infants who were very sick, those who failed otoscopic ear examination, and those whose parents did not sign the child assent forms were excluded.

Newborn hearing screening testing was first performed on the selected infants at BARH over the internet. This was conducted in real time via telehealth by an audiologist located at KBTH. As a control, similar hearing screening testing was conducted face-to-face on the same infants by a trained facilitator located at BARH. Parameters such as test results and testing duration of the two methods were compared and analyzed statistically.

Instrumentation

The equipment and materials used in the present study included a software-controlled computerized newborn hearing screening device, computers, webcams, internet access, remote access/control software, and a sound level meter.

The distortion product otoacoustic emissions (DPOAE) device, Bio-Logic AuDX DPOAE system was used for the newborn hearing screening test. This DPOAE device permitted usage for hearing screening via telehealth as well as the conventional on-site face-to-face approach. A default protocol for newborn hearing screening that used 'Pass/Refer' criterion was adopted. This default protocol used two primaries, $f1$ (low frequency) and $f2$ (high frequency) primaries with their respective intensities, $L1$ of 65 dB SPL and $L2$ of 55 dB SPL, to generate DP-gram of the test ear. The default Bio-Logic AuDX DPOAE protocol also used a test frequency ratio ($f2/f1$) of 1.22. In the present study, Pass outcome of the DPOAE hearing screening test was defined as $DP - NF \geq 6$ dB SPL (in which DP is the distortion product and NF is noise floor) in $\geq$3 of 4 test frequencies (2.0, 3.0, 4.0, and 5.0 kHz). Refer test outcome that signified either absent DPOAEs or measured DPOAEs fell outside the range of the established protocol of the newborn hearing screening test (adapted from Yu et al, 2010).

The Bio-Logic AuDX DPOAE device was connected through a USB port to a remote computer (Dell Inspironl E1405 laptop computer [Dell Technologies Inc, Round Rock, TX] on the MS Windows® XP operating system [OS] [Microsoft Corporation, Redmond, WA]) located at BARH. The application software of the DPOAE device was installed on the remote computer, and the DPOAE icon was placed on the desktop for easy access.

The host computer (Hewlett-Packard 630 Notebook [Hewlett-Packard Company, Palo Alto, CA] running on MS Windows® 7.0 platform) was used by the audiologist located at KBTH to establish virtual connection with the remote computer over the internet. This host computer with a built-in webcam was connected to the internet by means of a cellular mobile network. The remote computer was installed with a stand-alone webcam (USB Logitech Carl Zeiss Tessar 2.0/3.7 2 MP; Logitech International S.A., Switzerland) and connected to the internet by a 3G Huawei mobile Wi-Fi.

TeamViewer version 8.0 (remote access software; TeamViewer GmbH, Germany) was installed on both the host and remote computers. With internet access, this application software was used to establish a virtual connection between the host audiologist's computer at KBTH and the remote computer at BARH. The virtual connection between these two computers enabled the audiologist at KBTH to have full access to the remote computer's desktop. This configuration granted the audiologist access to the DPOAE device's icon on the remote desktop. It also allowed the audiologist to use the host computer to operate the DPOAE device connected to the remote computer from the host site (KBTH).

TeamViewer 8.0 is equipped with video, voice over IP, instant messaging, and conference call capabilities. This TeamViewer software and the webcams of the host and remote computers were configured to enable real-time video and audio communication between the host and remote sites. A sound level meter (Realistic® SLM) was assembled to monitor the noise intensity levels at the remote site while testing was in progress.

Infection Control

To prevent infections and cross contamination among the infants, strict infection control measures were followed. Equipment used, working areas, as well as contact areas were disinfected between tests. New disposable probe tips were used for each infant tested.

Procedure

The study adopted the synchronous telehealth model in which infants were tested over the internet by an audiologist located at a distant region. Using this model, a remote access software (TeamViewer version 8.0) was installed on the host and remote computers located in KBTH and BARH, respectively. The DPOAE device used for the hearing screening was connected to the remote computer. The DPOAE device's application software was also installed on the same computer. Figure 1 shows the telehealth set-up at BARH (remote site). To assist in telehealth applications at the remote site, an audiology graduate with eight months of training in pediatric DPOAE hearing screening and telehealth instrumentation was sent to BARH to serve as a facilitator. The facilitator assisted in DPOAE probe insertion and computer applications at the remote site.

With internet connectivity, the remote TeamViewer generated a unique identification and a password that were shared with the audiologist at KBTH. Figure 2 shows the remote TeamViewer's desktop interface. On input of the remote TeamViewer's identification and password in the host TeamViewer, a virtual connection was established and the audiologist's host computer instantly took over the desktop operations of the remote computer located at BARH. This permitted the audiologist to have virtual access to the DPOAE icon on the remote desktop

Figure 1. Telehealth technology set-up at BARH (remote site). (This figure appears in color in the online version of this article.)

to operate the DPOAE device through its application software installed on the remote computer.

By initiating testing remotely, the audiologist conducted real-time DPOAE hearing screening tests on the infants located at BARH while being physically located at KBTH as illustrated in Figure 3. Remote testing was initiated by means of the DPOAE icon on the remote desktop. Before testing, the facilitator located at BARH inserted the ear probe of the DPOAE device in the infant's external ear canal after which the audiologist was signaled to initiate the hearing screening test over the internet. Communication between the audiologist and the facilitator was achieved through the video conferencing interface of TeamViewer software (Figure 4). This also permitted the audiologist to concurrently see the infants tested as well as their mothers.

To determine comparability of telehealth test results and testing duration, the conventional face-to-face onsite approach for carrying out DPOAE hearing screening was also conducted on the infants. The conventional onsite method (COM) was conducted to serve as the research control for the telehealth method (THM). The facilitator performed the COM by manually manipulating the controls of the DPOAE device to test the infants at BARH face-to-face (Figure 5).

These two methods were scheduled such that while one ear was tested by the audiologist over the internet via telehealth that same ear was retested face-to-face by the facilitator while the DPOAE ear probe was still inserted in the external ear canal. This strategy was used to control variations in DPOAE amplitudes that result from differences in ear probe insertions. The order of testing was varied to control for order effects.

Again, the noise levels in the testing room at BARH were constantly monitored and the infants were tested while they were calm and still.

Data Analysis and Results

The Spearman's correlation coefficient analysis was invoked to test the strength of correlation of DPOAE test results between THM and COM. A paired t-test was used to determine the level of significance between the testing duration of the two methods. For all analyses, an alpha level of <0.05 was used as the level of statistical

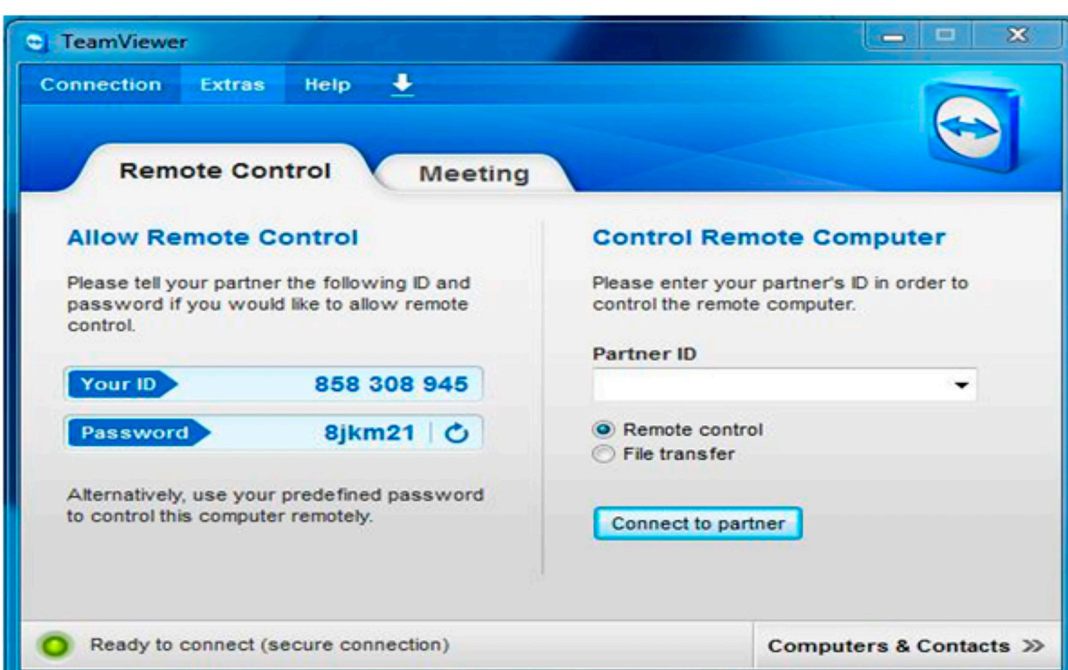

Figure 2. Desktop screen of TeamViewer 8.0 software on remote computer located at BARH. (This figure appears in color in the online version of this article.)

Figure 3. Regional map of Ghana illustrating interregional newborn hearing screening conducted via telehealth. The audiologist (bottom right) performing the hearing screening test is located at KBTH in the Greater Accra Region. The infant tested (top left) is located at BARH in the Brong Ahafo Region. Facilitator (top left) inserts the DPOAE device's probe into the infant's external ear canal after which the audiologist initiates hearing screening test over the internet. The arrows illustrate the virtual connection between the host and remote computers at KBTH and BARH, respectively. (This figure appears in color in the online version of this article.)

significance. Statistical Package for Social Scientists (SPSS) version 16.0 was used for the data analysis.

Table 1 shows Spearman's Correlation Coefficients between test results of THM and COM. As shown in Table 1, the analysis revealed a strong positive correlation between DPOAE test results of THM and COM. Table 2 shows the statistical results of the mean (m), standard deviation (s.d.), and paired t-test statistic of the testing duration of the two screening methods. As depicted by the analysis in Table 2, the mean testing duration of THM was 27.287 (s.d. = 27.373) and that of COM was 24.689 (s.d. = 27.169). Testing duration of THM was 2.598 seconds slower than that of COM. However, the inferential statistic showed that the difference in the testing duration between THM and COM was not statistically significant [$t_{(99)} = 1.309$, $p > 0.05$].

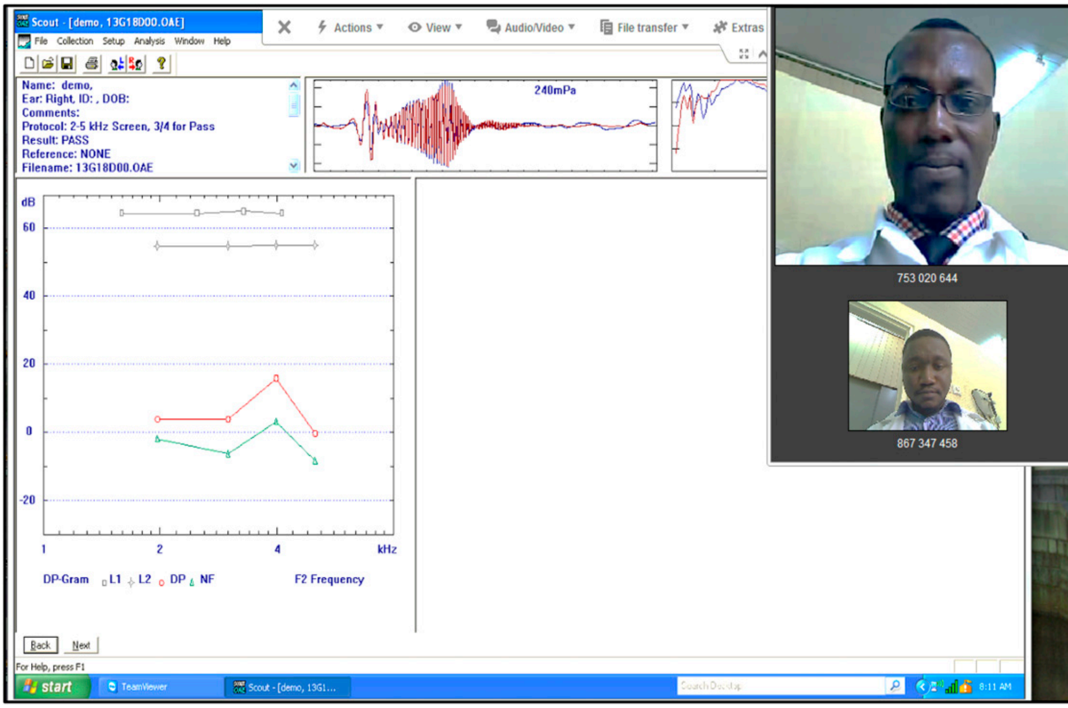

Figure 4. Audiologist (bottom) and facilitator (top) in a video interaction through TeamViewer version 8.0 software. (This figure appears in color in the online version of this article.)

DISCUSSION

The study was designed to assess the feasibility of using telehealth to extend newborn hearing screening services across Ghana. This was accomplished by comparing the test results and testing duration between telehealth and the conventional face-to-face on-site methods of conducting DPOAE newborn hearing screening.

Figure 5. Facilitator conducting conventional face-to-face on-site DPOAE hearing screening test on an infant at BARH. (This figure appears in color in the online version of this article.)

Table 1. Newborn Hearing Screening Test Results: Spearman's Correlation Coefficient (r_s) of DPOAE Test Results between THM and the Conventional Face-to-Face On-Site Method (COM)

	COM (kHz)			
THM (kHz)	2.0	3.0	4.0	5.0
2.0	0.778*			
3.0		0.878*		
4.0			0.857*	
5.0				0.823*

Note: * is significant at $p < 0.05$.

Analysis of data from the study showed a strong correlation between DPOAE test results of THM and COM. The strong positive correlation between DPOAE frequencies of THM and COM ($r_s = 0.778, 0.878, 0.857$, and 0.823, $p < 0.05$ @ 2.0, 3.0, 4.0, and 5.0 kHz, respectively) suggest that the test results of the two methods were highly comparable. This means that the method used to conduct the hearing screening did not significantly affect the DPOAE test result. The observed difference in the test results was due to factors other than the method used. These findings are consistent with a study by Schmiedge (1997), which reported similar strong correlation coefficients (r = 0.884, 0.850, and 0.848 @ 1.0 kHz and r = 0.908, 0.964, and 0.892 @ 4.0 kHz) (Schmiedge, 1997). Although the present study showed strong correlations in DPOAE test frequencies, the reported coefficients were lower compared with Schmiedge's data (r_s = 0.778, 0.878, 0.857, and 0.823 @ 2.0, 3.0, 4.0, and 5.0 kHz, respectively, versus r = 0.884, 0.850, and 0.848 @ 1.0 kHz and r = 0.908, 0.964, and 0.892 @ 4.0 kHz). This was attributed to differences in testing environments of the two studies. Schmiedge's study took place in a sound treated booth, whereas the present study was performed at the neonatal intensive care unit block of BARH. The intermittent noises that emanated from electric equipment, babies, and staff of BARH might have affected the present DPOAE results, hence the lower correlation values compared with that of Schmiedge's study. The recorded ambient noise intensity levels of the testing room ranged from 40 to 60 dB SPL. DPOAEs are low-level signals and the presence of high noise intensity levels can obscure their signals (Katz et al, 2009). According to Katz et al (2009), high ambient noise levels elevate DPOAE noise floor, which in effect affects the magnitude of the DPOAEs. In the present study, DPOAEs in the 2.0 kHz region were the most affected (r_s = 0.778).

Table 2. Newborn Hearing Screening Test Duration in Seconds: the Mean, s.d. and Paired *t*-Test Statistic of DPOAE Test Duration between THM and the Conventional Face-to-Face On-Site Method (COM)

Medium	N	*m*	s.d.	df	*t*	*p*
THM	100	27.287	27.373	99	1.309	0.194
COM	100	24.689	27.169			

With respect to DPOAE test duration (measured in seconds), the present study showed that the testing duration between THM and COM was not significant [$t_{(99)} = 1.309, p > 0.05$]. The observed difference in test duration between THM (m = 27.287, s.d. = 27.373) and COM (m = 24.689, s.d. = 27.169) was due to chance. The testing duration of THM was found to be 2.598 seconds longer than COM. This lag in testing duration observed in THM was attributed to a delay in "command-to-response" time between the host computer and the remote computer interfaced with the DPOAE device. During THM testing, there was apparent time delay before the DPOAE system at BARH responded to commands from the host computer. The delay was attributed to low internet bandwidth (<100 kbs) used. Low internet bandwidth becomes congested while large data files are transmitted. The remote access software, TeamViewer version 8.0, used video and voice over IP for real-time audio-visual interaction between the audiologist and facilitator. These video and audio files were large and might have congested the bandwidth, thereby slowing transmission of information from the host computer to the remote computer. However, in a related telehealth study, Penteado et al (2012) attributed the delay in THM to the distance between the host and remote sites and that the farther the distance the slower the speed of data transmission and vice versa. These authors also attributed the time lag in telehealth to the type of OS used by the computers. Microsoft Windows® OS was installed on the computers used in the present study. According to Penteado et al (2012), Microsoft Windows® OS manages tasks based on interruptions and functional priority, thereby causing delays in real-time data transmission over the internet.

None of the reported telehealth studies using DPOAEs (Schmiedge, 1997; Elangovan, 2005; Krumm et al, 2007; 2008) compared testing duration between THM and COM. It was, however, reasoned that a delay of ~2.6 seconds recorded in the present study was clinically insignificant and therefore more cost efficient to use telehealth rather than travelling many hours for newborn hearing services. The application of tele-audiology will save Ghanaians the cost and burden of travelling long distances to access pediatric audiological services.

Using telehealth, newborn hearing screening can be dovetailed into the hub and spoke concept of hearing health care delivery in Ghana (Ribera, 2011). Under this concept, KBTH, staffed by audiologists armed with knowledge and skill in pediatric audiological services, could serve as the hub. Hospitals in all ten regions of Ghana could become linked to the hub as spokes as depicted in Figure 6. With this design, newborn hearing screening and other infant hearing services would be provided via telehealth to children located in the ten regional health care facilities linked to the hub. This arrangement will allow access to pediatric hearing services, reduce

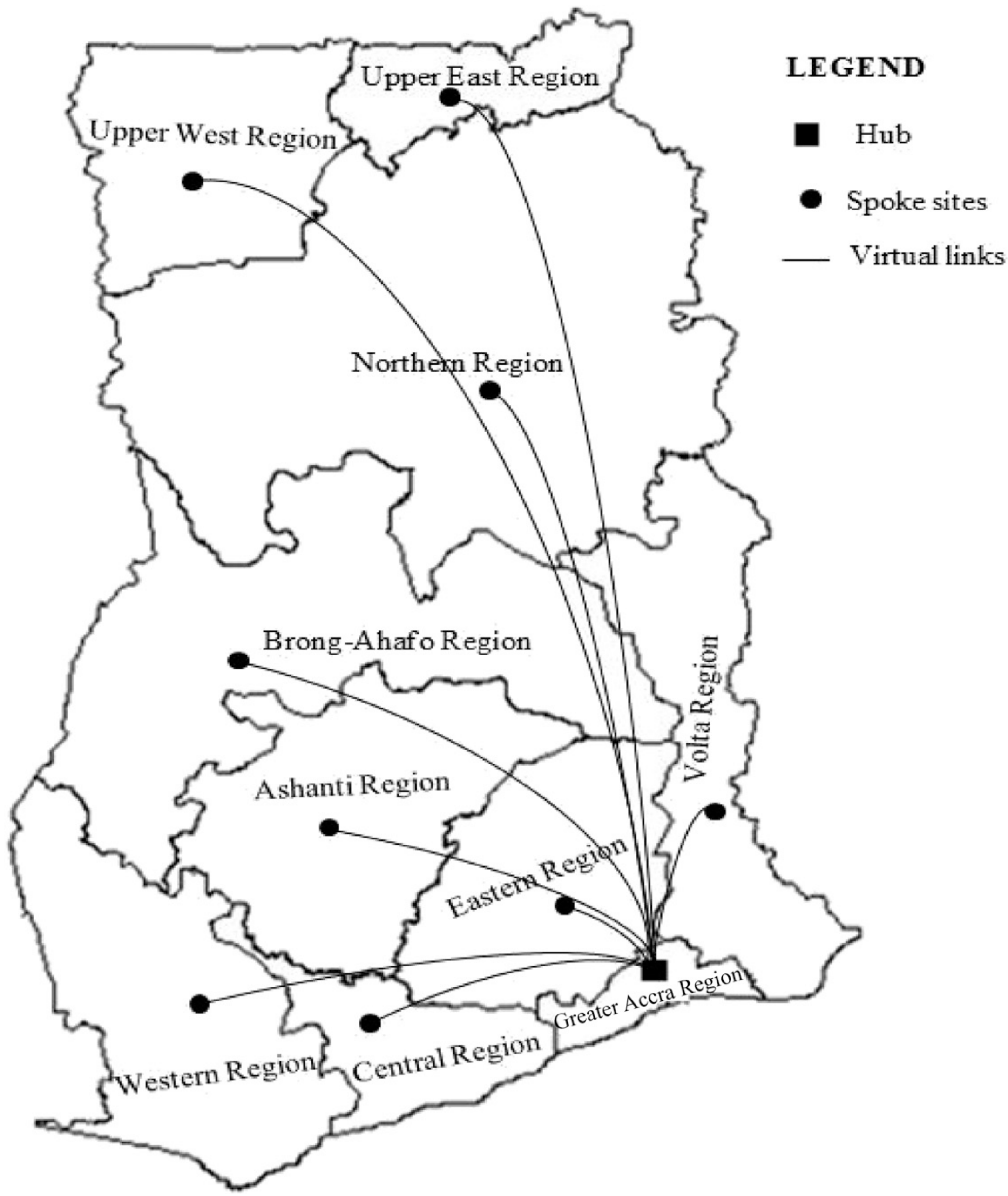

Figure 6. Regional map of Ghana showing the proposed hub-and-spoke design for newborn hearing screening and other infant audiological services via telehealth in Ghana.

long travel times, reduce cost to parents, and enhance interaction between hearing health care professionals and patients (Ribera, 2011).

CONCLUSION

The present study has shown the potential of using telehealth to extend newborn hearing screening to the Brong-Ahafo Region of Ghana. However, this study ought to be replicated in the remaining nine regions to validate the present findings and also to highlight the challenges peculiar to each region. In such studies, trained nurses, health technicians, or health assistants ought to be used as facilitators at the remote site to help in probe placement and computer applications. In addition, future telehealth studies in Ghana should investigate the feasibility of other pediatric hearing services such as comprehensive diagnostic assessments, hearing aid fittings, parental counseling, and posthearing aids' fitting follow-ups. Last, the perceptions, acceptance and satisfaction of Ghanaian parents accessing infants hearing services via telehealth must be assessed before fully establishing an interregional network of pediatric teleaudiology services in Ghana.

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