Remote Interaction and User Research:
Anaesthetic Preadmission Activity

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Abstract: In the absence of telehealth technology, rural patients must travel to a regional or metropolitan hospital for a preadmission consultation one week before their surgery. Currently, examination of the patient's chest using a stethoscope (auscultation) is not possible over a telehealth network as existing digital stethoscopes have been designed for in-person auscultation. We report on the initial phase of research which ultimately aims to design a digital stethoscope for use in the telehealth context. This initial research phase describes the complexity of the activity of preadmission clinics and the implications for the design of the stethoscope. The research is conducted through field studies of existing face-to-face and remote consultations.

Key words: user research, remote interaction, stethoscope, telehealth, field studies

1. Introduction

In Australia, people who require surgery and live in rural areas outside of the major capital cities must travel vast distances in order to receive pre-surgical care; this can be extremely expensive. An important pre-surgical service is a consultation with an anaesthetist who assesses the patient's suitability for anaesthesia. The pre-surgical anaesthetic consultation typically consists of an interview to obtain the patient's medical history and a physical examination by the consulting anaesthetist. The anaesthetist typically checks the patient's airway and examines their heart and lungs by using a stethoscope, a process known as auscultation.

Current videoconferencing technology enables doctors to conduct remote pre-surgical consultations which are very similar to face-to-face consultations. In a remote consultation, the anaesthetist is at the main hospital and the patient is at their local hospital, typically two to three hundred kilometers away. In the Queensland hospital system, the doctor and patient can see and hear each other through the state-wide telehealth videoconferencing system. Typically there will be a nurse at the remote location in addition to the patient. The only component of the patient's assessment that cannot be completed by the remote anaesthetist is auscultation of the patient's chest using a stethoscope. In some cases, the pre-surgical interview my be sufficient to ascertain the patient's general health and suitability for anaesthesia; however, in some cases, it is necessary for the doctor to listen to the patient's heart; for example, if they have a pre-existing condition which may affect their heart such as angina, previous heart attack or a heart murmur. In these cases it can be necessary for the patient to travel to the main hospital for assessment, return home and then return again for surgery in two to four weeks. Conducting pre-surgery auscultation remotely could offer significant benefits to patients in remote and rural areas by eliminating this unnecessary travel before surgery.

Thus, this research ultimately aims to develop a digital stethoscope for use with a telehealth communications network in order to allow doctors to examine patients remotely. In order to create a digital stethoscope that is readily accepted by the doctors and meets performance requirements, we are collecting data about the use of existing stethoscopes by conducting field studies of anaesthetic preadmission clinics. We have observed both face-to-face and videoconference clinics, and this paper presents our initial findings.

2. Stethoscopes

Stethoscopes are widely used by doctors for diagnosis of heart and lung disorders. Until recently, acoustic stethoscopes were the only type of stethoscope available. Now, however, there are electronic stethoscopes which offer diagnostic power similar to that provide by acoustic stethoscopes. Acoustic stethoscopes require a great deal of skill to use effectively. The particular skills required for effective auscultation involve being able to hear the exact sounds that represent different diseases and disorders of the heart and lungs. Doctors typically spend some time learning to use stethoscopes in medical school, and those who specialize in the diagnosis and treatment of heart and lung disorders often spend hundreds of hours learning the different diagnostic sounds.

2.1 Acoustic and Digital Stethoscopes

It is generally accepted that René Laennec invented the stethoscope in 1816 [4, 10]. This stethoscope – a cylinder of wood with a cone at the end – is different from the model that many doctors use today. Today's typical acoustic stethoscope is modelled after the Rappaport-Sprague binaural design from the 1940s. The part of the stethoscope that collects the sound from the chest is called the head, often with a bell on one side and a diaphragm on the other. The bell, a hollow cupped area, is applied gently to the skin and brings out low frequency sounds and murmurs [5] (p329). The diaphragm, a plastic disc, amplifies high-pitched sounds when pressed firmly against the chest [5] (p329). Despite the physical differences between Laennec's stethoscope and the form that is widely used today, the purpose of the stethoscope remains the same: to amplify the sounds made by the heart and lungs and transmit them to the ears of a skilled physician.

There are measurable differences in the sound capture and transmission properties of different acoustic [3] and digital [7] stethoscopes; however, it is unclear whether these differences are noticeable to doctors. Some sounds that are very low (below 50H) contain potentially valuable diagnostic information, yet many people are unable to hear these sounds with a conventional acoustic stethoscope [7].

Learning to use a stethoscope to perform auscultation is an important skill that is difficult to learn and takes a long time to master [5] (p395). The great variety of sounds made by the heart must all be learned, and a doctor must be able to distinguish subtle differences in these sounds. He must also separate them from the sounds of the lungs and from other noises inside the body.

Some [9] have argued that digital stethoscopes must provide audio fidelity equal to that of acoustic stethoscopes in order to be effective and leverage doctors' existing skills. While the technical quality of the digital stethoscope is important for accurate diagnosis, previous studies of remote examination have not looked at the interaction between doctor, nurse and patient or the way that a stethoscope mediates this interaction. As Hanna and Silverman [10] note, stethoscopes provide an intimate connection between doctor and patient. While doctors can be assumed to be skilled in using a stethoscope, many nurses have not been trained in auscultation of the chest, and patients are typically not users of stethoscopes as they are the objects of examination. The way in which doctors and other stethoscope users understand the use of a stethoscope is an area that is clearly worthy of further study. The great skill required to use a stethoscope effectively is often emphasised [4, 10, 12]; however, this framing of skill often assumes expertise in interpreting sounds, rather than an understanding of their tacit use by practitioners. This tacit use must be understood in order to design new devices that can function as stethoscopes.

Doctors are generally agreed that the use of stethoscopes should be encouraged [4, 10, 12]. While some doctors seem to be cautious about the increasing role electronic technology plays in what was formerly a process with seemingly little technological mediation [9], Murphy [12] notes that recent advances in computer science and signal processing have meant that greatly increased objectivity in the analysis of breath sounds is possible. This integration of new signal processing technology with the established process of auscultation points towards a renewed role for the stethoscope as a diagnostic tool for nurses [6] and doctors in remote medicine.

2.2 The Use of Digital and Remote Stethoscopes

There is some existing medical research on the use of digital stethoscopes for face-to-face and remote auscultation. The brief reviews below illustrate that the existing devices on the market have a level of diagnostic power that makes them useful in certain situations, such as in verifying the health of a patient's heart post-operatively [8]. However, the criticisms made of the devices are that (i) they are lacking sound quality [2, 8] and that (ii) remote interaction with the devices is problematic [2, 8]. This indicates that the design and use of remote digital stethoscopes are areas where a significant research gap exists.

Belmont and Mattioli [2] describe the testing of a narrow-bandwidth telephonic stethoscope (TS). The TS transmits sound over the ordinary telephone system. They tested the TS against an acoustic stethoscope (AS) by examining seventy-six children with a mean age of 10 years. One paediatric cardiologist examined each patient with the AS. Another paediatric cardiologist then examined the same patient using the TS, assisted by a nurse who placed the TS chest piece as directed by the doctor. Belmont and Mattioli [2] conclude that the TS was sufficiently accurate to 'distinguish between functional and organic murmurs and thus can detect heart disease' [2] (p780). They also state that the accuracy of the TS was greatest when used by an experienced examiner and the patient was older than five years of age.

Belmont and Mattioli [2] note that electronic stethoscopes (both narrow-band and wide-band) have a different 'feel' to acoustic stethoscopes. This is compounded by three aspects of the telephone system: narrow dynamic range or loudness; narrow dynamic resolution or capture of the variation in loudness; and reduced frequency response below 100Hz. These aspects of the telephone system can ' interfere with grading of murmurs or nuanced appreciation of signs such as S3 gallop, split sounds, and innocent murmurs' [2] (p783) – all of which are low frequency sounds. The stethoscope used in their study was designed to alleviate some of these problems by using bandwidth modulation, elevating the frequency of all sounds before transmission, and then restoring the sounds for the remote doctor.

Belmont and Mattioli [2] say that the nurse's initial unfamiliarity with the telephonic stethoscope could have lead to lower accuracy. They also say that the remote doctor did not discuss or instruct the nurse about the pressure with which the chest piece was applied, a factor that has a 'well established' [2] (p785) influence on the diagnosis of low-frequency murmurs. Fragasso et al [8] also note the importance of experience in the person who handles the remote stethoscope, noting that the quality of the sounds obtained by the remote stethoscope often 'required the intervention of the physician'. Belmont and Mattioli further note that autoauscultation, that is the positioning of the stethoscope by the patient themselves, was not feasible 'with current technology' [2] (p285).

Fragasso et al [8] describe a study into the 'feasibility and accuracy of a videophone-based system for remote cardiopulmonary examination of patients with heart failure' [8] (p281). Fifty patients were examined by two cardiologists, one with a conventional stethoscope and one using the video-phone based system transmitting over an ISDN line (a digital phone line). During each examination the cardiologists filled out a comprehensive questionnaire on their findings. Fragasso et al conclude: 'Remote cardiopulmonary examination appears as a feasible method for assessing patients with heart failure. Telestethoscopy can therefore be reliably used in the context of comprehensive telecare programs' [8] (p281). They also say that remote auscultation is difficult because of the lack of 'visual cues' (p281) and the 'inability to visually examine the patient' (p281). In some cases interference occurred in the remote auscultation setting, usually as the result of a mobile phone being left on in the room where the patient was located.

Fragasso et al [8] are confident of the benefits of remote auscultation; however, they caution that without knowing the patient's history and 'baseline cardiac and lung functions' (p285), it would not be appropriate to consider remote auscultation. Fragasso et al also say that the poor quality of the equipment they tested meant that it was not appropriate for doctors to examine heart-failure patients via remote auscultation without extensive medical history that could be used to aid their judgment. Wong et al [14] report on a trial of preadmission anaesthesia consultations conducted via telemedicine. They are cautious but positive about the potential of remote preadmission consultations to be conducted using telemedicine and a digital stethoscope.

Belmont and Mattioli [2] and Fragasso et al's [8] studies indicate that digital and remote stethoscopes are sufficiently different from acoustic stethoscopes to require doctors to learn new skills in order to use them effectively. However, Høyte et al [11] describe a study which was performed 'to determine whether the use of an electronic, sensor based stethoscope affects the cardiac auscultation skills of undergraduate medical students'. They did not find that students trained on the electronic stethoscope had significant differences in diagnostic ability to students trained on the acoustic stethoscope. This indicates that it is the remote and collaborative aspects of the interaction that are problematic, not the difference in the form of the device. The generally positive results reported by Belmont and Mattioli [2] and Fragasso et al [8] and the cautious optimism of Wong et al [14] indicate that a digital stethoscope for use in telemedicine would be valuable. The concerns expressed in the previous studies of digital stethoscopes in telehealth relate particularly to: the new skills that must be learned by the doctor and nurse, the 'lack of visual cues' [8] (p281), and the difficulty of remotely directing the placement of a stethoscope head [2]. This indicates that this is an area that needs in depth research that focuses on remote interactions and users' experiences with stethoscopes.

3. Study Design

Our research into the user issues surrounding the use of digital stethoscopes in telehealth has been undertaken through field and experimental studies. The research findings have identified new knowledge that contributes to the design and usability of the Telehealth Digital Stethoscope. This user research has been applied to our understanding of the relationships between users and the device which have been observed in the field. Our data has been collected through observation, think (talk) aloud protocol and retrospective protocols, interviews and focus groups. The main significance of our approach is that it identifies new knowledge that creates positive user experiences, and clarifies the users' needs and priorities. This will bring additional benefits in reducing the complexity of the device's design, and provide positive experiences to all user categories.

As participants, we have included 30 clinicians, 30 patients and 30 nurses selected randomly. Other relevant stakeholders – for example, telehealth facilitation staff – will be included as appropriate.

Data analysis has been supported by Noldus Observer [13] for observational data analysis and Atlas.ti [1] for verbal data analysis. The coding scheme has been developed through close examination of the videos of consultations. In this paper we report on the outcome and implications of the initial observations.

3.1 Results of Observations

Nine pre-admission consultations were observed and videotaped. Three of the consultations were undertaken by videoconference and six were face-to-face. Three of the face-to-face consultations were observed for the whole duration of the consultation, and three were observed during the auscultation portion only. This was at the request of the patients and doctors involved, due to the sensitive nature of some of the consultations. The type and length of the observations are shown in Table 1.

Following data collection, all observations were coded using The Observer software [13]. The coding scheme used is show in Table 2. The coding scheme was developed in conjunction with the data to accurately reflect the activities observed.

There are five groups of codes used to analyse the observations made of the pre-surgery consultations. The first group – 'stethoscope being used' – has one code which is used when the doctor places the stethoscope in the patient's ears. The second group – 'stethoscope head location' – has four codes: chest, back, right side of body and left side of body. No distinction is made if the stethoscope is on the left or right of the patient's chest or back; the right and left side codes are used when the doctor places the stethoscope head near the patient's armpit. The third group is used to describe which hand the doctors use on the stethoscope head, their right or left. On some occasions, one doctor used both hands on the head of his stethoscope. Other doctors seemed to be somewhat ambidextrous, switching hands in the middle of a consultation. The fourth code is used to capture which of the participants are speaking in the consultation: the doctor, the patient and the nurse (if present). The final code is used to describe the stage of the consultation, either interview or examination. In the observed full-length consultations, the doctors typically conducted some of the interview, then performed the examination, then returned to an interview stage.

Table 1: Summary of consultation observations

Consultation	Face-to-face / videoconference	Full or exam only
1	Face-to-face	Full
2	Face-to-face	Full
3	Videoconference	Full
4	Face-to-face	Exam
5	Videoconference	Full
6	Face-to-face	Full
7	Face-to-face	Exam
8	Videoconference	Full
9	Face-to-face	Exam

Table 2: Coding scheme

Coding Group	Codes
Stethoscope being used	Stethoscope in ears
Stethoscope head location	Chest; back; right side; left side
Doctor’s hand on stethoscope	Right hand; left hand
Speaking	Doctor; patient; nurse
Stage of consultation	Interview; examination

Table 3 shows the durations of various aspects of the face-to-face consultations. The full face-to-face consultations observed lasted between 9 minutes 58 seconds and 13 minutes 11 seconds – an average of 11 minutes 38 seconds. The examination-only consultations lasted between 1 minute 47 seconds and 4 minutes 26 seconds – an average of 3 minutes 11 seconds. The average examination time for all face-to-face consultations was 2 minutes 17 seconds, with an average time of 1 minute 11 seconds spend on auscultation. The remaining time in examinations is spent examining the patient’s airway. The average length of all face-to-face consultations observed was 7 minutes 24 seconds.

This demonstrates that the examination of the patient and the auscultation of the patient’s chest is a minor portion of the whole pre-admission consultation. In terms of time spent, assessing the general health of the patient is of greater importance than auscultation of the chest.

Table 3: Face-to-face observations, by consultation type (all times in minutes and seconds)

Observation	Stethoscope used	Examination	Type	Duration
4	01:09	01:43	Exam	1:47
9	01:11	03:09	Exam	3:20
7	02:32	04:23	Exam	4:26
1	00:59	01:25	Full	9:58
6	00:31	01:18	Full	11:45
2	00:42	01:41	Full	13:11
Average	***01:10.7***	***02:16.5***		***7:24***

An additional factor in the consultation was the type of anaesthesia required for the patient's upcoming operation. There are three different kinds of anaesthesia that are offered to patients. The first is a local anaesthetic which numbs only a specific area. The second is a regional anaesthetic which numbs an entire limb or area of the body. Sometimes a regional anaesthetic is called a nerve block, and may be administered in conjunction with a type of anaesthetic that makes the patient very relaxed and sleepy. Finally, there is the full general anaesthetic. In all cases, the questions asked in the consultation are the same. However, depending on which of these three broad types of anaesthesia a patient will be undergoing, the doctor has a different level of concern for the patient's general health. If the patient is to undergo a local anaesthetic, the doctor is not particularly concerned if the patient is (for example) old or has a poor heart, though they will make a note of it in the patient's file. For regional or general anaesthesia, the patient's ability to recover from the drugs is of high importance and the doctors are much more concerned with the patient's health and heart.

It seemed that the more generally healthy or younger the patient was, the more cursory the auscultation performed. Where patients were being examined for admission for heart operations and had preexisting heart conditions, as did the patients in Consultations 7 and 9, the doctor performed a much more involved and detailed examination (Table 1). Both patients in these consultations were males aged in their 70s. These examinations involved the men removing their shirts and lying bare-chested, face-up on the examination table in the consulting room. Table 1 shows that the examination times for Patients 7 and 9 – 3 minutes 9 seconds and 4 minutes 23 seconds, respectively – are much longer than the other examination times. The average examination time for the other patients is 1 minute 32 seconds. In all other consultations the patients remained clothed, although the doctors would lift a patient's shirt to obtain access to their chest or back if necessary. Some doctors had the patients stand while others allowed them to remain seated.

Table 4 shows that the videoconference consultations lasted an average of 9 minutes 52 seconds. In Consultation 8 the doctor attempted to examine the patient's airway, instructing the patient to demonstrate how far his mouth could open and how his head could tip backwards. The short time of this airway examination indicates that it was cursory.

Table 4: Videoconference consultations (all times in minutes and seconds)

Observation	Examination	Duration
3	-	11:08
5	-	8:38
8	0:17	9:50
Average		*9:52*

In all the videoconference consultations, the doctors are specifically concerned with the patients' general health, as they are in the face-to-face consultations.

Following two of the observed videoconference consultations the doctors commented that they would have liked to have had access to a method for examining the patient's chest. In one case, an otherwise fit middle-aged man mentioned that he had a heart murmur as a child, but that this had not been present for many years. The doctor commented that he would like to ascertain the absence of the murmur for himself. The patient then said that his general practitioner had confirmed the absence of the murmur, and this satisfied the doctor.

In all observed videoconferences the doctor sat looking at a 22 inch LCD television which showed the patient at the remote location. The approximate height of the image of the patient was 15cm. In one videoconference the patient was seated behind a desk; in the others, the patients were seated but otherwise unobstructed.

5. Discussion and Implications for Design

The doctors conducted the face-to-face consultations very similarly to videoconference consultations. The similarity between types of consultation seems to occur because the doctor's goal, regardless of consultation type, is the same: to assess a patient's suitability for anaesthesia. The doctors ask the same questions in much the same order in both types of consultation. The lack of difference between face-to-face and videoconference consultations is interesting because we had expected the different communication modality to affect the consultation. The full length face-to-face consultations and the videoconference consultations do not differ greatly in length or on any other measure captured by the coding scheme, with the exception that no stethoscope use takes place in the videoconference consultations. Either the videoconference modality has no great effect on the consultation, or the doctor's skill at conducting the consultation masks any deficiency in the technology.

The interview reveals whether or not a patient is generally healthy. In the case of healthy patients, the examination of the airway and heart is used to verify the impression that the doctor gained from the interview. However, when a patient is not generally healthy, has a pre-existing condition which is known to directly affect recovery from anaesthesia, or will be undergoing a heart operation, the doctor conducts a much more detailed auscultation. The intensity and type of examination is determined by the doctor's experience and the tools on hand.

The tools used by the doctors in a consultation are not limited to the stethoscope, which plays a limited role in most consultations. The most frequently used tool is the questionnaire that all doctors use with all patients in the observations. The doctors do not have a physical checklist or other guide for the questions they asked; they asked these in a way that seemed structured but not rigid. This lack of supporting material indicates that the questions that they ask are specific to anaesthetic preadmission consultations, and that they have a great deal of experience in asking them and in interpreting the answers.

Other tools that the doctors used included their stethoscopes, the results of patients' previous diagnostic tests and (possible) further diagnostic tests before they presented for surgery. In the observed consultations, the most frequent external tool was blood tests which were ordered for various reasons. It seemed that the results of the post-consultation tests would be included in the patients' records at a time after the consultation but before surgery.

It is clear that the tools that are used in pre-surgery anaesthetic consultations mediate the interaction between doctor and patient. Unlike previous studies [14] where subjects have shown aspects of both tacit and explicit knowledge, the anaesthetists observed mainly used tacit knowledge, fluently moving through the sub-tasks during the consultation.

The observations conducted so far indicate that the stethoscope and physical tools in general are not the only 'tools' that the anaesthetists use when they conduct pre-surgery consultations. Indeed, the videoconference consultations show that the doctors do not require a stethoscope in many instances, even though they would prefer access to one.

During the consultations the doctors spend a great deal of time making notes in the patient's record. This is a substantial folder than contains the results of tests and many other documents that relate to a particular patient. The record is used both during interactions with the patient and when the patient is not present. Thus, the patient record is another tool that doctors use during pre-surgery consultations.

Finally, it seems that observations of activity during pre-surgery consultations are not sufficient to understand how the doctors are using stethoscopes and other tools. Since the consultations involve two people, the doctors frequently explain some of what they are doing; however, it is apparent that they are so experienced that they do not verbalise much of their routine activities,. Therefore, a retrospective protocol will be necessary for understanding what occurs during pre-surgery consultations.

6. Conclusion and Further Research

We have conducted observational research of anaesthetic pre-surgery consultations. The consultations were conducted face-to-face and by videoconference. We found that both types of consultations were very similar; this indicates that the doctors' consultation skills were able to mask any deficiency in the technology.

The significance and innovation of this research is multi-fold. Our approach addresses several important problems that are shared by several significant application domains within remote (rural) health care. While we are developing new methods and techniques that will directly contribute to advancing knowledge within the specific domain of auscultation, this knowledge will be transferable to other domains. Our findings show that videoconferencing consultations are highly structured and moderately complex. They also indicate that more research is needed to understand how stethoscopes and other tools used by clinicians and other relevant users (e.g. nurses) mediate experiences during remote health assessment. This understanding will provide direction for the design of a digital stethoscope around the activity.

The results of this project are significant because they will provide health care professionals with a well researched situational analysis of factors influencing remote patient assessment using digital stethoscope technology. Ultimately, the research will lead to the development of an advanced tool that will enhance a clinician's capacity to effectively assess a patient irrespective of demographic and geographic boundaries.

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8. References

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