Original

Experimental Study on the Articulation of Heart-Sound Auscultation Skills of Experienced Nurses

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Abstract

Auscultation, a practical skill required in nursing, is an important basic method of noninvasively collecting patient information and performing physical assessment. However, studies regarding the skills associated with this method are scarce. Therefore, we aimed to articulate auscultation skills by assessing 10 experienced nurses, each with at least 5 years of experience in advanced medicine. Our study found that nurses identified abnormal heart sounds at different time points depending on the associated disease. Points of identification were defined by at least a 200-ms delay of normal heart rates from the abnormal heart rate frequency bands. Moreover, our results showed that providing nurses with additional patient information increased the accuracy of diagnostic auscultation.

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―Key words―

practical nursing skills, auscultation skills

Background

The Japanese healthcare system will begin restricting overtime work in 2024. Under these circumstances, it will be extremely difficult to continue providing healthcare services that largely depend on physicians. Hence, it is necessary to develop a new healthcare system that does not depend solely on physicians.

Accordingly, the expansion of nurses' roles has attracted an increasing amount of attention in the medical field. In 2015, the Ministry of Health, Labour and Welfare implemented the Nurse Specified Acts System. Within the framework of this system, qualified nurses who have completed the relevant education requirements can administer certain treatments in place of physicians, in accordance with the instructions given from them. Substantial changes have been made to the roles of nurses in developed countries, including Japan, where nurses are required to master a vast array of skills for understanding patients' conditions and making diagnoses. Such skills are more advanced than traditional practical nursing skills[1][2].

Methods of learning practical nursing skills have been systematically developed and cover various topics, from assisting physicians in providing medical services to providing physical support to patients. However, the more advanced these skills, the more difficult it is to articulate them verbally. One study found that for a nurse to acquire advanced skills, he or she must have many years of practical nursing experience[3]. Auscultation, which helps a nurse understand the disease condition of a patient noninvasively during physical assessment, is a basic practical skill for nurses and is also an essential skill for diagnosing patients[4][5]. However, there is a dearth of research on nurses' auscultation skills. Although many previous studies have assessed vital sign measurement (which involves auscultation), most of these studies have been examination and intervention studies of students; they were intended to improve learning efficiency or to help students acquire skills through educational interventions[6][7]. These studies were focused on how and to what extent students mastered auscultation through means such as questionnaires. Few studies have been conducted on nurses' established auscultation skills in real-world settings. Furthermore, limited research exists regarding how nurses ac-

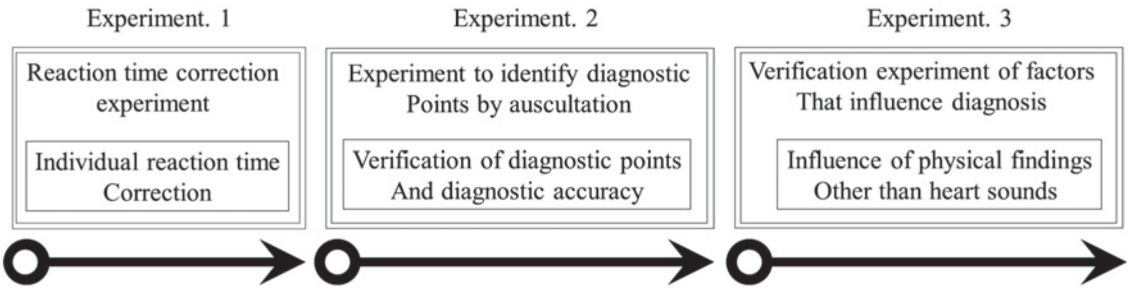

Fig. 1 Experiment outlines

quire said auscultation skills. The present study focused on the auscultation of heart sounds, which requires particularly advanced practical skills compared with other types of auscultation. This technique has an extremely high clinical significance with regard to understanding a patient's condition. We aimed to define points at which nurses distinguished sounds during heart-sound auscultation.

Methods

Participants

Ten nurses participated in this study, each with at least five years of practical clinical experience in advanced medicine. The nurses received an explanation of the study before giving their consent to participate. Fig. 1 shows the outlines of the experiments for the nurses participated. The purpose of experiment 1 was to measure the reaction time for individual sounds. The obtained reaction time was used as a correction time for all experiments. A specific sound was inserted into the sampled sound, and the reaction time at that time was used as a control example for the sound. The purpose of experiment 2 was to identify diagnostic points by auscultation. The sampled sound source was randomly heard, and the sound, which is the base point for diagnosis by auscultation, was measured. The purpose of experiment 3 was to clarify the effects of information other than sound on auscultation. We examined the effects of adding information such as medical history in listening to patient heart sounds.

Procedures and Ethical Considerations

Participants were asked to identify sounds used to make diagnoses during auscultation. Acoustic analysis software, which was developed based on VisibleWave (Mitsubishi Electric Engineering Company, Ltd.), was used in the experiment, in which the frequencies of sounds were analyzed and the identification time points were measured. Participants were asked to complete a survey form for the diagnosis of heart-sound auscultation. After obtaining permission from the participants, we provided them with the following information, both in writing and orally: the aim and methods of this study, the voluntary nature of participation, participants' right to withdraw from the study at any time, anonymity of participants, and exclusive use of data for research purposes. Participants indicated their consent to participate in this study by signing the consent form. This study was approved by the research ethics committee of Aichi Medical University (approval number: 171).

Details of Experiments

Auditory Reaction Times and Identification of Specified Sounds

The free software Audacity was used to create a specified sound with a frequency of 440 Hz and an amplitude of 0.8 size. A task was prepared in which the specified sound was randomly played throughout a period of 8 s. Participants were asked to perform auscultation using a stethoscope and to press the button when they identified the specified sound during the task. Their auditory reaction times to the specified sound were measured using VisibleWave. This experiment aimed to assess the reaction times of the participants to the specified sound.

Thereafter, participants were asked to identify the specified sound in another task, in which the specified

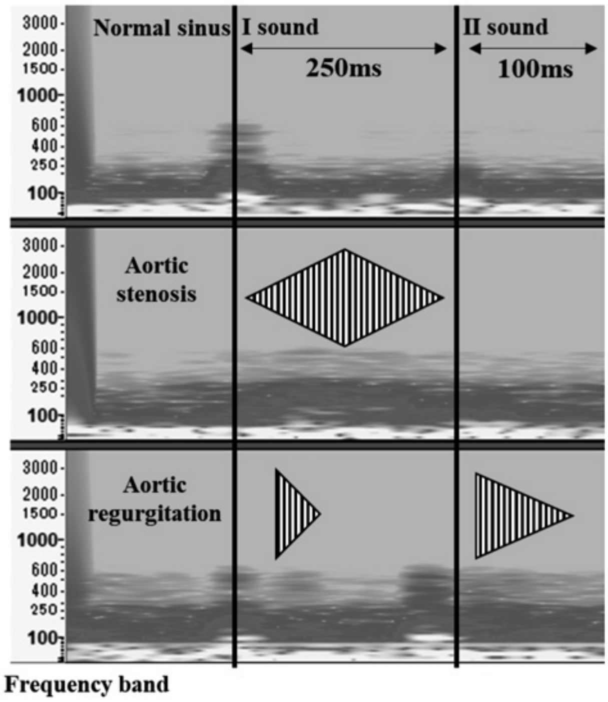

Fig. 2 Frequency characteristics by disease

sound and other sounds were randomly combined for a period of 8 s. These points of identification were measured in the same manner.

Identifying the Points of Diagnosis by Auscultation of the Model Heart Sounds

Three types of heart sounds were recorded using a Littmann electronic stethoscope (3M Japan Ltd.)—normal, aortic stenosis, and aortic insufficiency.

Fig. 2 shows the time per pulsation observed in sampled heart sounds and the characteristic differences in frequency. These sounds were configured in the physical assessment model Physiko (Kyoto Kagaku Co., Ltd.). The differences in frequency between normal heart sounds and abnormal heart sounds shown in Fig. 2 were as follows: for aortic stenosis, the difference was observed in the 250–400 Hz band in the 250 ms segment (between S1 and S2). For aortic insufficiency, the difference was observed in the 400–600 Hz band in the 50 ms segment following S1 and the 200 ms segment following S2. By using sampled heart sounds, the parts with clearly different frequencies between normal heart sounds and abnormal heart sounds were defined. By defining the identification points, the identification points by auscultation of the subjects will be clarified from the reaction times.

The three heart sounds were randomly allocated throughout the 8-s tasks. Participants were asked to auscultate and identify the sounds using a stethoscope. The sounds that led to diagnoses were identified, and the associated time points of identification were measured. The time point of identification was defined as the adjusted difference between reaction times.

Influence of Physical Findings Other than Heart Sounds

For this assessment, two tasks were administered: one task in which participants made a diagnosis by auscultating only the recorded heart sounds of a patient, and another task in which participants were provided with the patient's current history and radiographs as well as their heart sounds. The number of instances in which the sound that led to diagnosis was identified, and the results of the diagnosis were compared and examined between these two tasks.

Analysis

Identifying the Sound that Forms the Basis of Diagnostic Auscultation

We asked Mitsubishi Electric Engineering Company Ltd. to develop special acoustic analysis software

Table 1 Target person attribute

Sex	Medical department	experience of year
men	emergency room	6
men	intensive care unit	10
women	intensive care unit	14
women	emergency room	10
men	emergency room	5
men	Respiratory department	8
men	Cardiovascular surgery	8
men	intensive care unit	7
women	emergency room	5
men	intensive care unit	13

Table 2 Reaction time to sound

ID	Reaction time
1	380.6
2	278.1
3	413.6
4	402.0
5	505.3
6	349.1
7	432.2
8	368.0
9	442.1
10	411.0

based on VisibleWave for an experiment to identify sounds. The software was used to play the specified sound and to analyze the frequencies and the time it took for participants to identify the sound.

Statistical Processing

StatFlex ver. 7 (Medical Statistics Research Institute Co., Ltd.) was used for statistical processing. Pearson's chi-squared test was performed to analyze the difference between correct and incorrect heart-sound identifications. The Wilcoxon rank-sum test was performed to analyze the differences in results before and after the participants were provided additional patient information. Fisher's exact test was also performed to analyze the changes in participants' responses after additional patient information was provided. The level of significance was set at $p < 0.05$ for all tests.

Results

Participant Attributes

The attributes of the 10 participants are shown in Table 1. Seven of the participants were men, and three were women. Most worked in a ward for patients with serious conditions (e.g., the emergency department or intensive care unit). The number of years of experience in this type of ward was 5–14 years.

Identifying the Specified Sound During Auscultation

First of all, we measured the auditory response time for each specified sound three times for each participant, and defined the average value as the reaction time to sound. Table 2 shows the average reaction time obtained in three experiments for each participant's designated sound. From Table 2, the auditory reaction time of each participant ranged from 278 ms to 569 ms.

Next, seven designated sounds were inserted into the 15-second heart sounds, and the auditory reaction time to the designated sounds was measured.

Table 3 is the auditory reaction time of a specific sound inserted into the heart sound corrected by the auditory reaction time obtained in Table 2. From Table 3, the mean auditory reaction time obtained from each subject was 61.7 ms, and there was no significant difference in auditory reaction time.

Table 3 Auditory reaction time to the specified sound

ID	First time	Second	Third	4th	5th	6th	7th	Average
1	46.6	35.4	124.6	38.4	40.6	32.6	110.6	61.2
2	91.9	7.9	22.9	79.9	48.9	112.1	129.1	70.4
3	40.4	41.4	58.6	15.4	31.4	23.4	133.6	49.2
4	112.0	20.0	23.0	180.0	88.0	59.0	129.0	87.3
5	21.3	47.7	7.3	91.7	65.7	52.3	82.3	52.6
6	79.9	13.1	35.1	67.9	133.1	34.1	191.1	79.2
7	23.8	79.2	28.2	30.8	1.2	71.2	158.2	56.1
8	68.0	63.0	24.0	18.0	34.0	87.0	79.0	53.3
9	22.9	79.1	42.1	7.1	77.1	73.1	53.1	50.6
10	103.0	23.0	14.0	71.0	46.0	109.0	34.0	57.1
							Overall average	61.7

Table 4 Answer results for each disease

	n	rate	Correct	Incorrect
Normal sinus	57	64.9	37	20
Aortic stenosis	54	64.8	35	19
Aortic regurgitation	49	51.0	25	24

Table 5 Diagnostic results for each disease and sound diagnosis points

Symptom	Answer	Number of response	I-II sound	200 ms	300 ms	400 ms	500 ms	600 ms	
Normal sinus	correct	88	27	20	23	7	11	0	*P* = 0.064
	incorrect	18	4	3	6	5	0	0	
Aortic stenosis	correct	156	30	71	42	11	2	0	*P* = 0.024
	incorrect	175	51	48	54	21	1	0	
Aortic regurgitation	correct	75	18	0	1	6	25	25	*P* < 0.001
	incorrect	95	55	10	5	3	10	12	

Pearson's χ^2 text

All participants recognized the specified sound and made the relevant decision within 90 ms.

Identification of Sounds Used as a Decision-Making Indicator in Heart-Sound Auscultation

The rates of participants' correct answers are shown in Table 4. The correct answer rates when participants relied solely on heart sounds were 64.9% for normal heart sounds, 64.8% for aortic stenosis, and 51.0% for aortic insufficiency. Meanwhile, Table 5 shows participant responses by diagnosis and the time differences at the points of identification from the abnormal heart sounds. The results in Table 5 are also corrected based on the individual reaction times obtained in Table 2. When participants auscultated for normal heart sounds, most of the correct answers were diagnosed using heart sounds I to II. Many of the wrong answers were given 300 ms later than the heart sound 1-2. Pearson's chi-squared test was performed to analyze the differences in normal identification points between participants who gave correct answers and those who did not. The results indicated no significant difference between the two groups.

Thereafter, auscultation for aortic stenosis was analyzed. The largest percentage of correct answers was given at 200 ms, whereas the largest percentage of incorrect answers was given at 300 ms. A significant difference (p=0.024) was observed between participants who gave correct answers and those who did not.

Regarding auscultation for aortic insufficiency, the largest percentage of correct answers was given from 500–699 ms, whereas the largest percentage of incorrect answers was given between heart sound 1 and 2. A significant difference (p < 0.001) was observed between participants who gave correct answers and those who did not.

Findings from this study showed that when participants auscultated the chest for abnormal heart sounds,

Table 6 Effect of additional information on sound perception

ID	No information	Additional information	
1	10	11	
2	18	25	
3	28	32	
4	8	9	
5	8	11	z (1.98) $p<0.046$
6	1	6	
7	4	8	
8	12	11	
9	15	23	
10	19	15	

Wilcoxon rank-sum test

Table 7 Relevance of diagnosis and additional information

	correct	incorrect	
No information	1	9	$p<0.14$
Additional information	5	5	

Fisher's exact test

there was a 200-ms delay associated with aortic stenosis and at least a 300-ms delay associated with aortic insufficiency (relative to the points where abnormal frequencies were observed). Although the largest proportion of participants identified normal heart sounds in the 1–2 segment, the points of identification varied widely from 200 ms to 300 ms. Indeed, participants identified sounds with at least 200-ms delays rather than at the exact points where characteristic changes in frequency due to pulsation were observed.

Influence of Patient Information When Identifying Sounds in Heart-Sound Auscultation

Table 6 is an experiment using patient heart sounds, which is different from the previous experiments. In this experiment, we investigated how the perception of sound that leads to diagnosis changes depending on the presence or absence of patient information. Instances of correct identification increased for all participants when they were given additional patient information. A Wilcoxon rank-sum test was performed, and results of the analysis indicated a significant increase in this number after participants received the information (z=1.98; p=0.046). Meanwhile, Table 7 shows the number of correct answers for heart-sound diagnoses depending on whether patient information was provided. One participant gave correct answers without receiving patient information; four participants gave correct answers after receiving patient information. Fisher's exact test was performed to analyze the changes in participants' responses after they received the additional patient information. Results indicated no significant difference (p=0.14).

Discussion

Auscultation is a basic, highly versatile nursing skill used in various clinical settings. Effective education can shorten the time required to learn such basic skills. However, it is still extremely difficult for nurses to improve auscultation skills to the extent where they can correctly use them to diagnose a patient. One underlying factor is that nurses learn practical skills as tacit knowledge. Hence, this study aimed to convert tacit knowledge into explicit knowledge. In doing so, we attempted to visualize and describe sound identification skills, which are the primary basis of diagnostic auscultation. The results of this study found that, with regard to reference sounds in diagnostic auscultation, all participants recognized points approximately 200 ms after the actual diagnosis/identification point. When identifying a specified sound in the control model, all participants responded within 90 ms. Previous studies have found that auditory reaction times are faster than visual reaction times, and that tactile and auditory reaction times are approximately 120–140 ms[8)–10)]. In this study, the reaction times of participants were measured and adjusted before the results were analyzed. The occurrence of at least a 200-ms delay after an abnormal heart sound may indicate that participants recognized sounds differently in diagnostic auscultation than in the identification of a specified sound. Recognition of sounds involves differences in frequency (timbre) and changes in rhythm (pitch). Reactions to auditory stimuli are caused by reflexes in a manner similar to that of perception. As for the specified sound, the findings from this study correspond with those from preceding studies in terms of general auditory reaction time. However, the auditory reaction times of participants in this study clearly exceeded the general range of reaction time when they auscultated heart sounds. This delay may exist because experienced nurses do not solely rely on reflexive reactions to sounds; they also recognize other factors centered around the sounds. Additionally, a significant difference in diagnostic identification time was observed between participants who answered correctly and those who did not, suggesting that skills affecting the accuracy of diagnosis led to this slight time difference.

When participants were provided further information in addition to heart sounds, there was a significant increase in the number of correct identifications of the heart sounds leading to definitive diagnoses. More specifically, the number of participants who answered correctly increased from 1 to 4. Participants were asked to answer repeatedly for the point of identification where a decision was made during auscultation as long as measurement continued. Participants, therefore, continued to answer even after they identified the disease. In another experiment using heart sounds, 8 of the 10 participants identified sounds associated with diagnoses at an increased rate after receiving additional information. This suggests that information other than heart sounds affected the participants' recognition of sounds. Providing participants with additional information also affected their response related to the results of diagnoses, suggesting that providing a nurse with further information in addition to heart sounds may help increase the accuracy of their diagnoses.

It is a natural assumption that providing participants with more patient information increases the accuracy of their diagnosis. Indeed, in this study, the accuracy of sound identification in auscultation by an experienced nurse depended on whether patient information was provided beforehand. In other words, auscultation by an experienced nurse is not simply a matter of differentiating among sounds. Rather, it is a skill requiring complex thinking processes that can lead to higher diagnostic accuracy.

We used acoustic analysis software to visualize sound identification points by experienced nurses during diagnostic auscultation. We suggest that, in order for experienced nurses to effectively apply their auscultation skills, it is important that they not only distinguish different sounds but that they also consider potential diagnoses based on the sounds. Therefore, the existing auscultation training methods for nurses may not be effective; they simply help nurses learn how to distinguish different sounds. In these existing methods, nurses repeatedly hear normal heart sounds as a reference so that they can then recognize abnormal sounds. This study used acoustic analysis software to visualize the points at which experienced nurses distinguished heart sounds. Visually presenting the points at which heart sounds are recognized helps to reduce the amount of information required for a nurse to acquire this skill; therefore, it leads them to rely more on their knowledge than on simply distinguishing sounds.

Future studies are needed to examine how visually presenting points at which experienced nurses recognize heart sounds affects the acquisition of auscultation skills by less-experienced nurses.

Limitations

This study examined only nurses with at least 5 years of experience in an advanced medical setting. As it was difficult to recruit participants, we presented quantitative results from multiple experiments. Therefore, selection bias may have largely affected the results. In addition, the sampled sounds used in this study may differ from those heard in real-world clinical settings. Hence, it was extremely difficult to make a diagnosis based on the sampled sounds. Given that the rates of correct answers were low (50–60%), the difference between participants who answered correctly and those who did not could not be clearly shown. However, no previous studies have visualized auscultation by experienced nurses using measurement devices such as frequency analysis software. Therefore, this study has high clinical significance; it found that experienced nurses do not simply rely on distinguishing sounds when performing auscultation.

Conclusions

Our study found that nurses identified abnormal heart sounds at different time points depending on the associated disease. Points of identification were defined by at least a 200-ms delay of normal heart rates from the abnormal heart rate frequency bands. Moreover, our results showed that providing nurses with additional patient information increased the accuracy of diagnostic auscultation.

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References

1) Lesa R, Dixon A, et al: Physical assessment: inplications for nurse educators and nursing practice. Int Nurs 54 (2): 166—172, 2007.
2) Price CL, Han SW, et al: Advanced nursing practice an introduction to physical assessment. Br J Nurs 9 (22): 2292—2296, 2000.
3) Kawabe Fusako: Experience about physical assessment learning process of clinical nurses in the hospital. Tiba University journal 9 (1): 17—25, 2018.
4) Sonya Osborne, Clint Douglas, et al: The primacy of vital signs — Acute care nurses' and midwives' use of physical assessment skills-A cross sectional study-. International joural of nursing studies 52: 951—962, 2015.
5) Shelaine L Zambas, Elixabeth A Smythe, Jane Koziol-Mclain: The consequences of using advanced physical assessment skills in medical and surgical nursing. Int J Qual Stud Health Well-being 2016; 11: 10.3402/qhw.v11.32090, 2016.
6) Tanaka Akiko, Otaki Amae, Okamoto Akiko, et al: Effect of active learning study in measuring vital signs. The showa University journal of medical sciences 77 (1): 59—67, 2017.
7) Kumatani Naho: Development and evaluation of computer-assisted learning material on physical assessment. Journal of japan association of simulation-based education in healthcare professionals 3: 1—7, 2015.
8) Chocholle R：現代心理学 II　反応時間．白水社，1963, pp 87—185.
9) Seashore S, Seashore RH: Individual differences in simple auditory reaction timies of hands, feet and jaws. Journal of experimental psychology 29: 342—345, 1941.
10) Oyama Tadasu: The present status of reaction time studies. Ergonomics 21: 57—64, 1985.

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熟練看護師の心音聴取における聴診技術の可視化に向けた実験調査

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愛知医科大学看護学部

―キーワード―
看護実践技術，聴診技術

看護師に必要とされる実践技術の一つとして聴診技術がある．聴診技術とは，非侵襲的に患者情報を把握することが可能な実践技術の一つであり，患者の病態把握を目的としたフィジカルアセスメントを行う上で重要な基礎技術である．しかし，看護領域において看護師の聴診技術そのものに着目した研究は殆ど行われていない．そこで，本研究では高度医療の経験が5年以上ある熟練看護師10名を対象として，熟練看護師が持つ聴診技術の可視化を目的とした調査を行った．その結果，聴診による音を用いた心音異常の同定において疾患毎に異常と特定する部位が異なることや，正常心音とは異なる周波数帯を示す部位よりも200msec以上遅れた部位を同定ポイントとして認識していることを明らかとした．このことから聴診技術において音のみを判断基準とするのではなく，音を基点として疾患を特定する思考が影響している可能性を示した．また，聴診による診断において音以外の患者情報が聴診技術の精度に影響を与えることを明らかとした．

［COI開示］本論文に関して開示すべきCOI状態はない

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