Differences in Brain Activity of Skilled and Novice Nurses during Blood Collection

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Abstract: Nursing skills are highly implicit. No effective method has been established for passing them on to the next generation of nursing workers. This research represented an attempt to formalize the skills of skilled nurses. To evaluate human mental state and emotions objectively, we clarified differences in brain activity between skilled and novice nurses at the time of collecting blood from a patient. As a result, many skilled nurses tried to use their own knowledge for the blood vessels they faced for the first time, irrespective of the blood collection success or failure. However, some novice nurses face subsequent blood collection without reflecting on the clear factors leading to success or failure.

1 INTRODUCTION

In recent years, the population of Japan has been decreasing and rapidly aging. Concomitantly, demand for workers in the medical and nursing fields is increasing. Moreover, the sophistication and complexity of medical and nursing technologies are accelerating (Japan Cabinet Office, 2016). Therefore, developing human resources and improving skills in medical and nursing fields is important. The high turnover rate of nurses, especially the early retirement of new graduate nurses, has been a long-standing issue (Japan Nursing Association, 2018). According to a survey conducted by the Japan Nursing Association cites take many factors that are related to nursing skills, a gap between abilities at the end of basic nursing education and abilities required at nursing sites and to be required higher nursing skills than before, as one cause of turnover(Japan Nursing Association, 2004). For this reason, review of the education contents and the mode of education in basic nursing education is necessary. However, in the acquisition of nursing skills, a need exists to formalize tacit knowledge because it is difficult to transfer and pass on tacit skills such as "skills" and "knacks" possessed by skilled nurses to the next generation of workers (Naohisa, K. et al., 2004).

Thus, we attempt to clarify and formalize the skills (tacit knowledge) possessed by skilled nurses.
In this paper, we especially focused on the blood collection and aim to clarify the difference in brain activity between skilled nurses and novice nurses during blood collection.

2 RELATED RESEARCH

2.1 Tacit Knowledge of Nursing Skills

There are two types of tacit knowledge: "cognitive aspect" and "technical aspect"(Yujiro, N. et al., 1996). In the case of nursing skills, it is necessary to formalize both of them. Most of the research on the cognitive aspect is that there are subjective and qualitative approaches such as interviews with nurses. In the research on the technical aspect, we focused on skin development and pressure, which are the movements of auxiliary fingers during blood collecting, and tried to clarify tacit knowledge by comparing the skills of

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nurses and nursing students (Takeshi, M. et al., 2018), (Naoki, U. et al., 2018).

2.2 Biological Information

Biological information is generated during activities controlled by human autonomic nerves without human consciousness. Such information is related to the person's mental and physical state. Examples of biological information include pulse, respiratory rate, and brain waves.

2.2.1 Biological Information: Electroencephalogram

We especially examined brain waves in biological information and conducted a study measuring brain waves during nursing skills implementation. The electroencephalogram expresses a person's mental state and emotions more prominently than other biological information. The study suggested that the voice of a skilled nurse while performing intravenous injection leads the patient to a relaxed state (Tsuneo, K. et. al., 2016).

2.2.2 Biological Information: Cerebral Blood Flow

In this research, we newly focused on cerebral blood flow, which is one of biological information. It has been reported that the activate parts on the left and right sides of the brain reportedly differ and table 1 presents the respective brain characteristics. Cerebral blood flow is used as an objective index to evaluate technology and content in various fields (Lei, H. et. al., 2012), (Shinsuke, M. et. al., 2012). For this research, we estimate brain activity based on changes in oxygenated hemoglobin concentration in the cerebral blood flow. In earlier study, we measured cerebral blood flow during five consecutive blood collecting sessions, and qualitatively considered the state of brain activity flow during each blood collecting by skilled nurses and novice nurses (Takahito, T., 2018).

Table 1: Brain functions and features.

Right brain	Called "image brain," it is activated when thinking according to the image and emotion
Left brain	Called "Language Brain," it is activated when you think about things logically and understand the language

Therefore, this research further expanded the field of view, we particularly focused on the success and failure of blood collecting through five sessions.

We aimed to elucidate the state of brain activity flow when nurses succeeded or led from failure to success of blood collecting.

3 EXPERIMENT

3.1 Outline of Experiment

For the present research, we specifically examine the "blood collection technique" that is frequently used in nurse's daily work and measure the brain activity during puncture. Blood collection was performed using arm models for blood collection simulation. A patient role-player was set in front of subjects to give a sense of realism of blood collection. The nurse was able to collect blood while talking with the patient. Table 2 shows the experimental location and period. Fig. 1 portrays the experimental environment.

This research was conducted with the approval of the Ethics Committee of the Graduate School of Sustainable System Sciences, Osaka Prefecture University.

Table 2: Experiment place and period.

Implementation period	4 days from November to December 2018
Implementation location	practice room in Hospital A

Figure 1: Experiment environment.

3.2 Subject of Experiment

Subjects were 19 active nurses working at a hospital who agreeded to collaborate. Table 3 shows the ladder levels and the number of nurses. The ladder level is a nurse development and evaluation system and axis established by the Japan Nursing Association. It includes five levels of competence and career, ranging from a novice to an experienced practitioner: higher numbers denote higher nursing practice capabilities.

For the present research, we referred to the ladder level set by the hospital at which the target nurses work and divided them into two groups: novice nurses and skilled nurses.

Table 3: Nurse ladder lebel.

Implementation category	Ladder level	Number of people	Total
Novice nurse	I	9	9
	II	0	
Skilled nurse	III	4	10
	IV	4	
	V	2	
Total		19	

3.3 Used Equipment

3.3.1 Cerebral Blood Flow Meter

For analyzing brain activity, we used a wearable optical topograph (NIRS WOT-220; Hitachi Ltd.), a cerebral blood flow meter, to measure changes in oxygenated hemoglobin concentrations in cerebral cortical blood flow. This cerebral blood flow meter has 10 channels, each of which measures oxygenated hemoglobin in the cerebral blood flow.

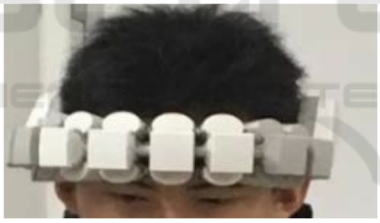

Figure 2: Wearing a cerebral blood flow meter.

3.3.2 Arm Model for Blood Collecting Simulation

For the blood collecting simulation, we used an arm model (LM-086; Koken Co. Ltd.), from which a nurse can select blood vessels to collect blood. Several types of blood vessel models can be used. Fig. 3 shows the arm model. Fig. 4 shows the type and difficulty of blood vessel models.

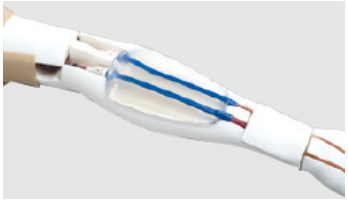

Figure 3: The arm model with the blood vessel model.

We explained in advance that exchanging multiple simulation model. However, participants did not know from which blood vessel model they will collect blood.

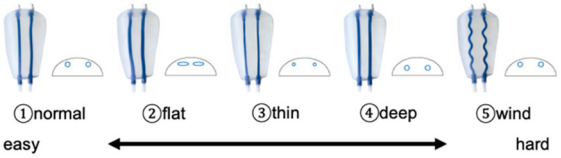

Figure 4: The type and difficulty of the blood vessel model.

4 ANALYTICAL METHOD

We examined the brain activity of nurses based on changes in hemoglobin concentrations in the cerebral blood flow obtained from experiments. The data are graphed. Features are extracted from the graph. The analytical procedure is presented below.

4.1 Channel Selection

Ten channels of the cerebral blood flow meter were divided into two areas, the left brain and the right brain. Then the average values of channels operating normally from each area were calculated. Normal operation required that to satisfy the two conditions: (1) the device is in the "Normal" state during calibration, and (2) the measured value does not detect an extreme abnormal value.

4.2 Graph Smoothing

It is difficult to interpret the overall characteristics even when graphed because the raw data obtained from the cerebral blood flow meter are noisy. Therefore, it might be necessary to smooth the graph by applying some processing in order to make it easy to ascertain the graph characteristics.

4.2.1 Graph Smoothing in Earlier Study

Earlier study removed noise on the raw data using the moving average method in order to facilitate interpretation of the characteristics of the graph. Subsequently, smoothing was performed by reducing the number of data by calculating root mean square (RMS) values. However, if RMS is applied to raw data that might be negative, then the output would be a positive value, which cannot represent brain activity accurately. Therefore, for this research, data smoothing was attempted by the following procedure.

4.2.2 Graph Smoothing in This Research

High frequencies above a certain threshold are often noise generated by the experimental environment and the life activity of the subject because cerebral blood flow gradually reflects changes in neural activity over time. Therefore, this time, noise was removed by application of Low Pass Filter.

4.3 Normalization

Analyses of Cerebral blood flow were made based on the amount of hemoglobin concentration change in each nurse because individual differences exist in the absolute amount of hemoglobin concentration change in the cerebral blood flow. The amount of change was expressed as a value of 0-1.

5 RESULTS AND DISCUSSION

One graph shows the transition of oxygenated hemoglobin concentration during five blood collections. The vertical blue line mark in the graph shows the following time points during one blood collection: (1) start of blood collection, (2) needle insertion, (3) needle removal, and (4) end of blood collection. In addition, the nurse ID and type of blood vessel model are shown in the graph. Each trial is separated by a red bold vertical line. The success (○) and failure (×) of blood collection are shown at the top of the graph.

5.1 Patterns of Skilled Nurse Success

The pattern monitored in Figure 7 is often seen by skilled nurse who completely succeeded in all blood collections. The transition of oxygenated hemoglobin concentration in both of right brain and left brain were highest at the first time and gradually decreased from the second to the fifth blood collection. In addition, the time required for blood collection was the longest at the first time and gradually decreased.

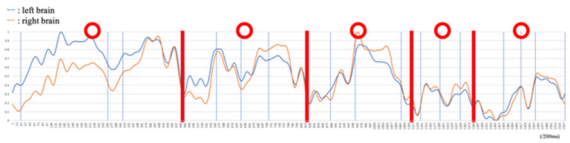

Figure 7: Example of a pattern of skilled nurse success.

Accordingly, it is considered that a skilled nurse who has high ladder level and high blood collection technique is gradually able to succeed in blood collection without considering because deep considering about success factor when succeed for the first time, they can grasp the knack.

5.2 Patterns of Novice Nurse Success

The pattern monitored in Figure 8 is often seen by novice nurse who completely succeeded in all blood collections showed the different graph from that of skilled nurse success pattern. The transition of oxygenated hemoglobin concentration did not gradually decreased from the second to the fifth like a skilled nurse. The transition of oxygenated hemoglobin, especially in the left brain, was flat from the first to the fifth blood collection.

Accordingly, it is considered that someone of novice nurses who has low ladder level and low blood collection technique was not able to succeed blood collection without deep considering from the second time on too because they could not understand the success factor even when succeeded.

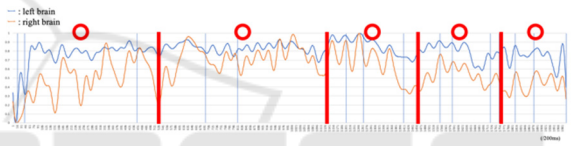

Figure 8: Example of a pattern of novice nurse success.

5.3 Patterns Leading to Success from Failure of Skilled Nurse

The pattern monitored in Fig. 9 is often seen by skilled nurse who failed once the first or second blood collection and succeeded more than three times thereafter. The pattern was similar to the pattern of skilled nurse success. The transition of oxygenated hemoglobin concentration was the highest at the first time and gradually decreased from the second to the fifth blood collection.

Figure 9: Example of a pattern leading to success from failure of skilled nurse.

Accordingly, it is considered that a skilled nurse who has high ladder level and high blood collection technique is thereafter able to success blood collection because they finded and improved the cause of failure by deep considering about it when failed.

5.4 Patterns Leading to Success from Failure of Novice Nurse

The pattern monitored in Fig. 10 is often seen by novice nurse who failed once the first or second blood collection and succeeded more than three times thereafter. The pattern was similar to the pattern of leading to success from failure by skilled nurse but the transition of oxygenated hemoglobin concentration was different from that when skilled nurses failed in blood collection.

Accordingly, it is considered that a skilled nurse who has low ladder level and low blood collection technique collected blood at the first time without deep considering because not finding success factor, they could not understand what should do when they collected blood.

Figure 10: Example of a pattern leading to success from failure of novice nurse.

6 CONSIDERATION

This research clarified differences in brain activity between skilled nurses and novice nurses during blood collecting from the viewpoint of changes in oxygenated hemoglobin concentration in the cerebral blood flow. Results indicate that many skilled nurses tried to use their own knowledge for the blood vessels they faced for the first time, irrespective of the blood collection success or failure. However, some novice nurses face subsequent blood collection without reflecting on the clear factors leading to success or failure. Therefore, the brain continues to be active every time, even if the failure continues or succeeds. From the above, one can infer that, at the time when the first blood collection is completed in the future, the nurses are encouraged to reflect on their performance. From that point forward, the skilled nurse and the novice nurse will specifically examine what points to connect to the next blood collection analyses and will verify the difference. Results demonstrate such reflection and subsequent success are necessary experiences to clarify the tacit knowledge of skilled nurses in nursing techniques that are difficult to verbalize.

7 FUTURE WORK

We think to use another biological information like gaze and pressure and develop index that can measure nursing skills proficiency based on all of biological information.

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