Title: Variation in health care providers' perceptions: decision making based on patient vital signs

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Abstract: Clinical decision making plays an imperative role when delivering healthcare services. To assist healthcare practitioners in decision making activities, Early Warning Scorecards (EWS) have been developed to classify patients based on their vital sign readings. This paper aims to evaluate the variation among healthcare practitioners' perceptions of vital signs critical ranges and priorities, and if there is a variation between decisions made based on paper-based Modified EWS (MEWS) and electronic MEWS. A survey is conducted to analyse these variations for six vital sign parameters. Further investigation is carried out on the variations in decisions made for six simulated patients using the paper-based MEWS and eMEWS. Thus, the variations of decisions made for a given patient among the survey participants are analysed in light of paper-based MEWS and eMEWS. Therefore, this paper contributes to both theory and practice by identifying variations in health care providers' perceptions when deciding the actions/treatment of patients.

Keywords: Modified Early Warning Scorecard (MEWS); electronic Modified Early Warning Scorecard (eMEWS); Clinical Decision Support System (CDSS); perception

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INTRODUCTION

Serious physiological abnormalities resulting in unexpected admission to an Intensive Care Unit (ICU), Coronary Care Unit (CCU) or in some cases the unexpected death of the patient (Hillman et al., 2001, 2002; Kause et al., 2004) can often be detected in the vital signs of patients hours before the catastrophic event (Jacques, Harrison, McLaws, & Kilborn, 2006). Nonetheless, medical studies have identified deficiencies in the detection of such abnormalities in vital signs and delay or failure to take appropriate action (Buist, Bernard, Nguyen, Moore, & Anderson, 2004; Sax & Charlson, 1987). Vital signs include, but are not limited to, electrocardiography (ECG), blood pressure, pulse, body core temperature, and oxygen saturation (Varshney, 2008). Healthcare practitioners often monitor and measure these vital signs to determine a patient's level of physical functioning. Normal vital sign values for the average healthy adult while resting, according to Dugdale and David (2011), are:

- Blood pressure: 90/60 mm/Hg to 120/80 mm/Hg
- Breathing: 12–18 breaths per minute
- Pulse: 60–100 beats per minute
- Temperature: 97.8–99.1 degrees Fahrenheit/average 98.6 degrees Fahrenheit

It is noteworthy, however, that these vital signs are subject to change according to the age, sex, weight, exercise tolerance and condition of a patient. Paper-based documentation protocols and guides have been developed to assist healthcare professionals with managing patient records, capturing vital sign data and delivering care. To assess vital signs, many healthcare practitioners or organisations utilise approaches such as Early Warning Scorecard (EWS), Modified Early Warning Scorecard (MEWS) and electronic Modified Early Warning

Scorecard (eMEWS). In the context of this paper, a healthcare organisation refers to an affiliation that, in compliance with standards and quality metrics, is responsible for delivering health services. Private and public hospitals are considered examples of healthcare organisations. The paper-based documented protocols and approaches attempt to provide a reference for critical boundaries of vital signs and their priorities when interpreting these data. Such approaches have been established based on prior studies including Schein, Hazday, Pena, Ruben, and Sprung (1990) and Morgan, Williams, and Wright (1997) and are in wide use (Kyriacos, Jelsma, & Jordan, 2011). Each of the approaches utilised by healthcare practitioners or organisations is depicted in more detail below.

Early Warning Scorecard (EWS), also referred to as Patient at Risk score (Rees 2003), is a simple scoring system for bedside monitoring to serve as a clinical add-on using routinely collected vital sign data (Groarke et al., 2008). Various sets of physiological parameters are used to calculate EWS score. An EWS may be calculated for a patient based on a combination of seven physiological parameters including (i) mental response, (ii) pulse rate, (iii) systolic blood pressure, (iv) respiratory rate, (v) temperature, (vi) urinary output and (vii) oxygen saturation (i.e. SpO2) (Groarke et al., 2008).

Initially, EWS was established as a paper-based approach. However, in recent years, early warning systems have begun to move from paper observation charts to electronic platforms. This helps to automate the calculation of scores and generation of patient records. Studies exploring EWS on hand-held computers as an aid to derive an EWS score have demonstrated improvement in the accuracy and efficiency of calculating EWS while being acceptable to nurses as the main users (Mohammed, Hayton, & Wight, 2009). The use of hand-held computers has been found to speed up the process of calculating EWS scores, at an average of 1.6 times faster than using pen and paper (Prytherch et al., 2006).

Developed on the concept of the paper-based EWS (Morgan et al., 1997), Modified Early Warning Scorecard (MEWS) is also a paper-based approach in the provision and capturing of patient-related information and vital signs (Kyriacos et al., 2011). According to O'Kane et al. (2010), a wide variety of MEWS is currently utilised globally. MEWS also aims to identify patients at risk of serious deterioration or adverse events (Gardner Thorpe, Love, Wrightson, Wlash, & Keeling, 2006; Stenhouse, Coates, Tivey, Allsop, & Parker, 2000; Subbe, Kruger, Rutherford, & Gemmel, 2001) by associating vital sign derangement with a score (Smith et al., 2006; Tarassenko, Hann, & Young, 2006). In effect, the MEWS serves as a reference point for interpreting raw vital sign datasets and their associated action protocols. As the name suggests, MEWS is a modified version of EWS whereby color-coded ward observation charts are introduced and physiological ranges are modified. Mitchell et al. (2010) found that deployment of color-coded ward observation charts such as MEWS assists in making timely intervention in detecting patient deterioration. As a consequence of timely intervention, rates of unplanned admissions to ICU and unexpected death in hospitals are improved. Similar to the EWS, MEWS also evolved from a paper-based approach to a digitised approach for capturing vital signs. This evolution is termed electronic Modified Early Warning Scorecard (eMEWS). A brief overview of each scorecard is presented in Table 1.

Table 1. Overview of scorecards utilised for detecting patient risk.

Scorecard	**Description**
Early Warning Scorecard (EWS)	Simple scoring system for bedside monitoring to serve as a clinical add-on using routinely collected vital sign data (Groake et al., 2008). Conducted manually for each patient.
Modified Early	MEWS is a modified version of EWS (e.g. different parameters

Warning Scorecard (MEWS)	associated with vital signs). Vital sign data is manually sampled and recorded. This approach is dependent upon the healthcare providers' competency in accurately obtaining and recording patients' vital sign readings (O'Donoghue et al., 2011)
Electronic Modified Early Warning Scorecard (eMEWS)	eMEWS represents a shift from paper based warning systems to electronic systems. eMEWS is often designed and developed around the paper-based MEWS guidelines and associated protocols. It permits the automatically sampling and recording of vital sign values with absolute and true scores determined (O'Donoghue et al., 2011).

Studies have shown that the use of standardised observation protocols, in particular MEWS, increases the mean patient observation frequency per nursing shift on ICU discharge (De Meester et al., 2012; Hammond et al., 2012). Thus, there is strong evidence in the extant literature that demonstrates the need to have an early warning system in place within hospitals. In summary, the management of patient data and the capturing of vital signs have evolved throughout the years from EWS to MEWS to eMEWS (Figure 1).

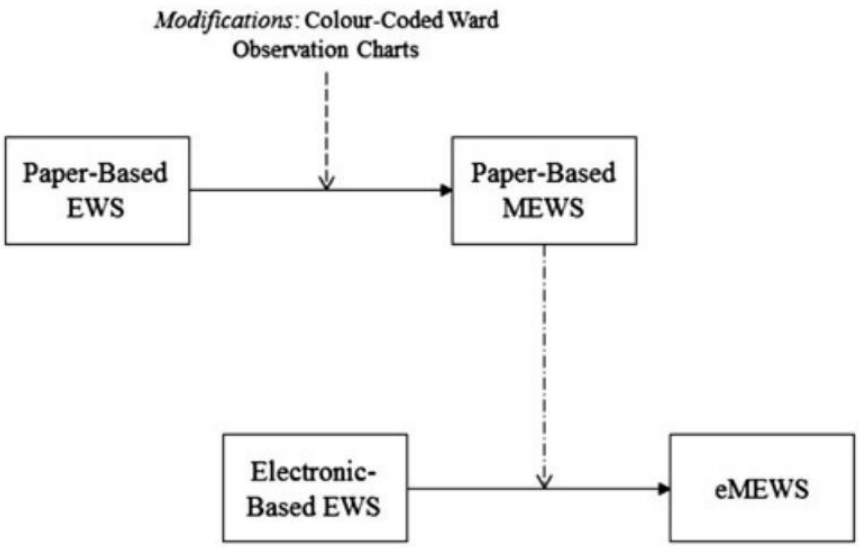

Figure 1. Early Warning Scorecards (EWS), Modified Early Warning Scorecard (MEWS), Electronic Modified Early Warning Scorecard (eMEWS).

DECISION MAKING

Decision making is central to health policy and medical practice (Kaplan & Frosch, 2005). Clinical decision making is a problem-solving activity that focuses upon defining patient problems and selecting appropriate interventions (Higuchi, 1997). Healthcare professionals have a range of assistive tools available to assist with their decision making process (for example, tools that assess vital signs to calculate a risk score, and clinical decision support systems). As outlined in Section 1, vital signs are associated with a score (0, 1, 2, 3) which is representative of the physiological derangement from a normal range. In MEWS, individual vital sign parameters (for example, pulse and temperature) collected from a patient are given a score indicating each vital sign's derangement from a normal range. The sum of the individual scores becomes the patient's MEWS score which corresponds to a suggested course of action (O'Kane et al., 2010). Hence, the greater the MEWS score, the greater the likelihood of patient deterioration (O'Kane et al., 2010). Based on the score a patient receives, the healthcare practitioner makes a decision and acts accordingly.

Moreover, healthcare professionals often make decisions pertaining to a patient with the assistance of Clinical Decision Support Systems (CDSS). The concept of CDSS commenced with the aim of developing expert systems that could think and behave as medical staff would in meeting a patient (Miller, 1994). CDSS gradually became a tool in assisting medical staff to make decisions (Berner & Lande, 2007). In order to improve the quality of care provided to the patient in a more timely fashion, CDSS aims at providing users with information and knowledge presented to them according to the protocols and guidelines in place (Berner, 2009). The utilisation of computerised CDSS has resulted in reductions in cost and medication errors, and improvement in clinical practices (Kaushal, Shojania, & Bates, 2003; Kawamoto, Houlihan, Balas, & Lobach, 2005; Pestotnik, Classen, Evans, & Burke, 1996). In addition, adherence to computerised clinical reminders is found to be high (Agrawal & Mayo-Smith, 2004). MEWS, which is a CDSS, was developed as a tool for supporting healthcare professionals in their decision making activities (Kawamoto et al., 2005).

Healthcare professionals do not solely depend on CDSS to assist them when making a decision. Another important component required by healthcare professionals when making a decision is a measure of patient's health status (i.e. pain rating), which Clark, Yang, Tsui, Ng, and Bennett Clark (2002, p. 241) regard as "the fifth vital sign". It is argued that decisions in healthcare are primarily based on the healthcare providers' perception of the pain that patients undergo (Davis, Gribben, Lay-Yee, & Scott, 2002). While healthcare providers' experience and knowledge play an important role in their decision making activities, differences in their assessment of pain against patients' assessment has been reported by the literature (Bowman, 1994; Coll, Grégoire, Latimer, Eugène, & Jackson, 2011; Guru & Dubinsky, 2000; Krahulec, Schmidt, Habacher, & Kratzer, 2012; Marquié et al., 2003; Marquié, Duarte, Mariné, Lauque, & Sorum, 2008; Solomon, 2001). Previous studies have compared the patients' and healthcare providers' ratings of pain, as a measure of patients' health status. One study has revealed a significant difference between the two in relation to surgical pain (Bowman, 1994). Statistically, significantly lower acute pain rating has been reported by nurses and physicians than that reported by the patients in an emergency department, as shown in Guru and Dubinsky (2000). Another study shows that there is a significant relationship, although not a strong one, between the two in the context of burned patients (Van der Does 1989). These findings remain evident in recently published work (c.f. Coll et al., 2011; Krahulec et al., 2012; Marquié et al., 2008).

Considerable variation in the practice of different areas of healthcare is evidenced by the literature (Busato & Kunzi, 2008; Davis, et al., 2002; Howard, 2012; Lay-Yee, Scott, & Davis 2013; Wennberg, 1984, 2002, 2011). The "variation in expert opinion the complexity of medical knowledge, the variation in physician decision making potential, and human error" is described as parameters associated with variation in medical practice (James & Hammond, 2000, p. 1001). The impact of such variation is often overlooked and its implications are revealed to affect the delivery of healthcare and thus patient satisfaction (Noon, Hankins, & Côté, 2003).

Robbins and Judge (2007, Ch. 5) define perception as "a process by which individuals organize and interpret their sensory impressions in order to give meaning to their environment". These sensory impressions – perceptions – may be significantly different from the objective reality. However, perception is the basis of an individual's behaviour and decisions. Furthermore, Bucknall (2003) has identified a strong influence of the context and environment on clinical decision making. In particular, she identifies patient situation, resource availability and interpersonal relationships as three environmental factors influencing clinical decision making. Similarly, the literature supports situation (e.g. time, settings and social situation) as one of the factors influencing perception (Robbins & Judge, 2007).

Therefore, the objective of this paper is to evaluate healthcare practitioners' perceptions of vital signs contributing to their decision making activities. To achieve this objective three research questions are proposed:

(1) What are the variations among healthcare practitioners' behaviour in defining threshold values for vital signs?
(2) How do healthcare practitioners prioritise vital sign parameters when carrying out decision making activities?
(3) Is there a variation between decision making activities based on MEWS and eMEWS?

This paper therefore investigates the variation among the healthcare providers' perceptions of priorities and critical boundaries of vital signs. In addition, their decision making activities are reviewed in the context of a Medical Assessment Unit (MAU) where MEWS is deployed.

This paper continues by describing the methodology employed in this research paper (Section 3). Section 4 represents the results of the evaluation in terms of the variation of healthcare providers' perception of vital signs' critical ranges, variation of their preferences in prioritising vital signs and the impact that eMEWS may have on the actions healthcare providers take in comparison to the paper-based MEWS. Section 5 is a discussion of the findings. Conclusions, future research opportunities and implications for theory and practice are provided in the conclusion of this paper (Section 6).

METHODOLOGY

To achieve the objectives of this research, an eMEWS prototype was initially developed based on the paper-based MEWS guidelines (see Appendix I) and associated protocols which exist in a collaborator hospital. The hospital collaborating in the research is a public hospital located in Ireland. This hospital has already deployed paper-based MEWS guidelines. Moreover, eMEWS was developed to utilise the benefits of computerised CDSS. The eMEWS prototype allows storage and retrieval of five patient monitoring parameters including (1) pulse, (2) systolic blood pressure, (3) respiratory rate, (4) SpO2, and (5) temperature in the form of time stamped trends. These five parameters are those used to calculate the MEWS score in the collaborating hospital. However, manual entry of additional parameters such as the use of supplementary oxy gen, Glasgow Coma Scale (GCS) and urine output is also supported. A screen capture of the eMEWS prototype is presented in Figure 2 This figure demonstrates the colour coding techniques that are applied to the trends of vital signs, most recent readings and the protocol associated with the most recent MEWS score. The colour coding scheme corresponds as follows: green to zero, amber to one, orange to two and red to three and higher MEWS scores. The MEWS score of the patient presented in this figure (Figure 2) is two, as respiratory rate and SpO2 are both in the amber region and are the only vital sign parameters that are not green. The healthcare practitioner is required to perform certain actions based on the score calculated (Appendix II).

The prototype is designed and implemented based on the paper-based MEWS layout that had been in use already. However, additional features are utilised. For example, the prototype supports the monitoring of patients by facilitating summary reports and track history features. The prototype is interactive compared to a paper-based MEWS. For instance, users can select vital sign parameters and are able to graph their selection over a period of time and evaluate a patient's overall health status. This prototype was evaluated in a workshop with healthcare providers taking part in a survey. The workshop was held in the collaborating hospital MAU ward. Prior arrangements were made to allow for the maximum number of participants taking part in the workshop. All participants who took part in the workshop filled out the survey. Thus, healthcare providers who were available to attend the workshop and were not seeing a patient took part in the survey. A total of 490 nurses and medical doctors work in the collaborating hospital.

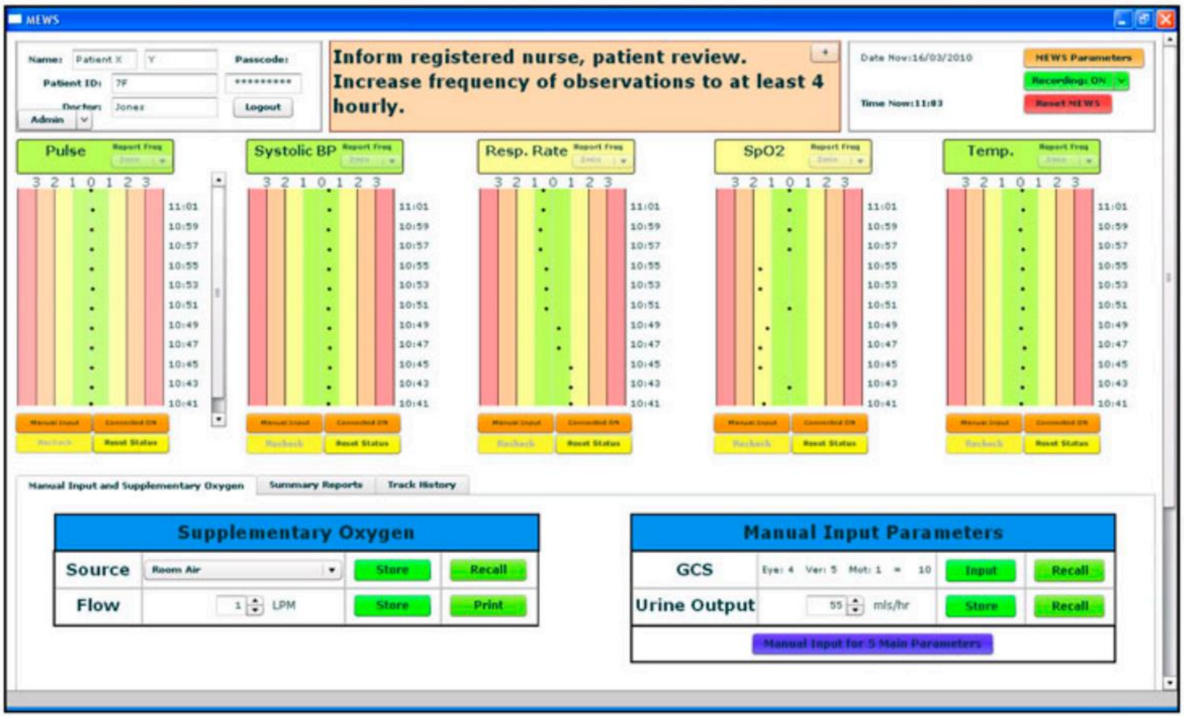

Figure 2. Electronic Modified Early Warning Scorecard (eMEWS) prototype user interface.

The next step towards achieving the research objective involved the implementation of a survey. Surveys can be implemented in either paper-based or electronic formats (McCoy, Marks, Carr, & Mbarika, 2004). For this study, a paper-based survey was implemented in two phases. The survey was utilised to assess (1) the impact of eMEWS on healthcare providers' perception of vital signs' upper and lower boundaries, and (2) the decisions healthcare providers perform when confronted with a patient. The two phases of the survey were conducted as part of an hour-long workshop with health care providers. The workshop consisted of an introductory presentation, demonstration of the eMEWS prototype, hands-on interaction with the prototype, and the survey. The introductory presentation, demonstration of the eMEWS prototype and hands-on interaction with it allowed the survey participants to familiarise themselves with the prototype and its functionality and have a brief period of training prior to the study. Thus, a source of bias in the study was eliminated. The two phases of the survey are designed as below:

(1) *Phase one of the survey:* general questions about the use of paper-based MEWS were addressed in this phase. Participants were asked to prioritise a list of the vital signs they were provided with. They were also asked to calculate MEWS scores and specify the actions they would perform for each of the six simulated patient cases. The simulated patient cases were created in consultation with a senior healthcare professional who did not take part in the study to avoid biased results. To ensure that both stable and unstable patients are captured in the study, three patient cases from each cohort are simulated. This leads to a total of six cases. Completing this component of the survey enables the researcher to explore research questions one and two.
(2) *Phase two of the survey:* participants were presented with the vital sign data and MEWS score for six simulated cases in the eMEWS prototype interface. These cases are the same as those presented in Phase one. Therefore, building from the previous phase, participants were asked to describe the action they would take for each case. This phase was performed to explore research question three.

The variations among the healthcare providers' perceptions of vital signs' critical reading ranges and their priorities in ranking the six vital sign parameters are analysed in respect to the three selected categories of participants. The Kruskal-Wallis one-way analysis of variance is utilised to analyse vital signs' critical reading ranges (Kruskal & Wallis, 1952). According to Chan and Walmsley (1997), the Kruskal-Wallis one-way analysis of variance determines whether three or more independent groups are the same or different on some variable of interest (i.e. vital signs' critical reading ranges, in this study) when an ordinal level of data, interval or ratio level of data is available.

Furthermore, to assess the variations among the actions healthcare providers would take using paper-based MEWS and eMEWS, responses from survey participants for the six patient cases are compared in two groups – responses made based on paper-based MEWS, and responses made based on eMEWS interface. A text analysis method is performed to examine the variation between the decisions made with paper-based MEWS and eMEWS. Following a review of the action descriptions provided by the participants, it is revealed that the minimum and maximum numbers of words that describe an action are two and seven, respectively. Thus, the occurrences of phrases with two to seven words were found by an online tool named Textalyser (Textalyser, 2013). Since abbreviations and numbers are widely used in the action descriptions, letters and numbers are considered as words when analysing the text.

RESULTS

From the 490 individuals working as nurses or medical doctors, 71 individuals took part in the workshop. Thus, the response rate is about 14%. As depicted in Table 2, of the total 71 participants who took part in the survey, 11 were medical doctors, 56 were nurses and the remaining four did not specify their expertise. Enquiring about participants' experience with the paper-based MEWS, 24 participants had over 24 months' experience, 23 had between 18 and 24 months, and eight and nine respondents had less than 12 and less than six months of paper-based MEWS experience, respectively. Two participants had no prior paper-based MEWS experience and five did not respond to this question. Participants had no prior exposure to the eMEWS prototype. This eliminates a source of bias in the evaluation.

Assuming that nursing experience has an impact on healthcare providers' perception of patients' status and their decision making activities, participants are classified into four categories based on their nursing experience. The four categories include healthcare providers who have (1) over 10 years, (2) five to 10 years, (3) two to five years, and (4) up to two years of nursing experience. Of the total of 71 participants who took part in the evaluation of the eMEWS prototype, 46 participants had over 10 years of nursing experience, 13 had five to 10 years, eight had two to five years, and two had up to two years of experience. Two participants did not respond to the question about their level of experience. Given the distribution of population in each category and its small sample size (n = 2), the category of participants with up to two years of nursing experience was omitted from further analysis.

Table 2. Respondent profiles.

Description	Count (n=71)
Occupation	
Medical Doctor	11
Nurse	56
Not Specified	4
Experience with Paper-Based MEWS	
24+ Months	24
18-24 Months	23
Less than 12 Months	8
Less than 6 Months	9
No Prior Experience	2
Not Specified	5
Experience with eMEWS	
No Experience	71
Nursing Experience	
10+ Years	46

5-10 Years	13
2-5 Years	8
Less than 2 years	2
Not specified	2

Healthcare providers' perception of critical reading ranges

Participants were asked to "state what they would regard as threshold values for vital signs when they would contact a doctor for patient review". Upper and lower critical values for pulse, systolic blood pressure, temperature and the lower boundaries for O2 saturation and urine output were gathered in response to this question.

To test the assumption that the three samples originate from the same distribution, that is, the healthcare providers' experience does not have an impact on their perception of critical values, the Kruskal-Wallis one-way analysis of variance by ranks was applied to the data. The Kruskal-Wallis one-way analysis of variance is a suitable method for this analysis due to the fact that three independent samples are the subject of analysis. The null hypothesis in this case is that the three populations with three different levels of nursing experience from which the three samples are selected have the same median and thus they are not significantly different. Table 3 shows the mean ranks, n, H, degree of freedom, and p-values calculated using this method for the six vital sign parameters. The null hypothesis is only rejected if the p-value is less than 0.05. From Table 3, the null hypothesis is rejected for respiratory rate upper boundary with a p-value of 0.0121. The next lowest p-value is associated with the pulse upper boundary; its value is 0.0623. Thus, the null hypothesis is rejected for one vital sign. That is, at least two populations from which these samples are collected have different medians.

		Pulse		Systolic BP		Resp. Rate		Temperature		O_2 Sats.	Urine Output
		High	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**Low**	**Low**
Mean Ranks Categorised based on experience	**2-5 years**	32.8	25.9	27.8	29.7	33.6	31.7	31.1	28.2	29.5	26.1
	5-10 years	19.7	36.4	26	28.9	17.9	27	31.5	34.5	33.1	37.4
	> 10 years	28.4	36.1	35.3	22.6	24.4	19.4	25.9	31.9	24	25.9
n Categorised based on experience	**2-5 years**	38	38	36	36	37	37	40	39	38	36
	5-10 years	12	12	12	12	12	12	12	12	12	12
	> 10 years	8	8	8	8	8	8	8	8	8	8
	H	5.55	4.91	1.71	1.26	8.83	3.82	0.65	1.37	1.4	4.57
	df	2	2	2	2	2	2	2	2	2	2
	P	0.0623	0.0859	0.4253	0.5326	0.0121	0.1481	0.7225	0.5041	0.4966	0.1018

Table 3. The Kruskal-Wallis one-way analysis of variance for three categories of participants.

Prioritising seven parameters

To establish an understanding of the variation of participants' preferences in prioritising vital sign parameters, they were asked to "indicate the priority that should be applied to the vital signs parameters based on their own experience". This was achieved using a seven-point Likert scale ranging from highest priority (1) to lowest priority (7). The seven parameters considered for this question include (i) pulse, (ii) systolic blood pressure, (iii) respiratory rate, (iv) temperature, (v) O2 saturation, (vi) urine output and (vii) Central Nervous System/Glasgow Coma Score/Alert, Voice, Pain, Unresponsive (CNS/ GCS/AVPU). Table 4 shows the number of respondents ranking each parameter at a level between 1 and 7 (1 being the highest priority, 7 being the lowest). From this table CNS/GCS/AVPU is ranked the highest by 19 participants. Pulse, systolic blood pressure, respiratory rate, temperature, urine output and O2 saturation are then ranked to the lowest priority. Figure 3 shows the variation between the selected parameters at various levels. From this diagram it is clear that the highest and lowest priorities are being selected to be CNS/GCS/AVPU and urine output, respectively, while there is not a clear distinction between the ranks at levels 2 to 6. Participants agreed on the highest and lowest priorities of vital sign parameters in a clear and concise fashion, while they failed to do so for intermediate levels.

Table 4. Number of participants ranking each vital sign parameter. Rank 1 is of the highest priority, while Rank 7 is of the lowest priority.

Priority	**Pulse**	**Systolic BP**	**Resp. Rate**	**Temp**	**O_2 Sat**	**Urine Output**	**CNS / GCS / AVPU**
Rank 1	7	7	8	3	4	5	19
Rank 2	11	2	3	0	9	0	4
Rank 3	7	9	2	4	7	0	1
Rank 4	2	6	9	5	4	1	0
Rank 5	3	6	6	4	3	2	3
Rank 6	2	2	2	11	3	4	3
Rank 7	0	0	2	4	1	19	4
Rank n	**32**	**32**	**32**	**31**	**31**	**31**	**31**

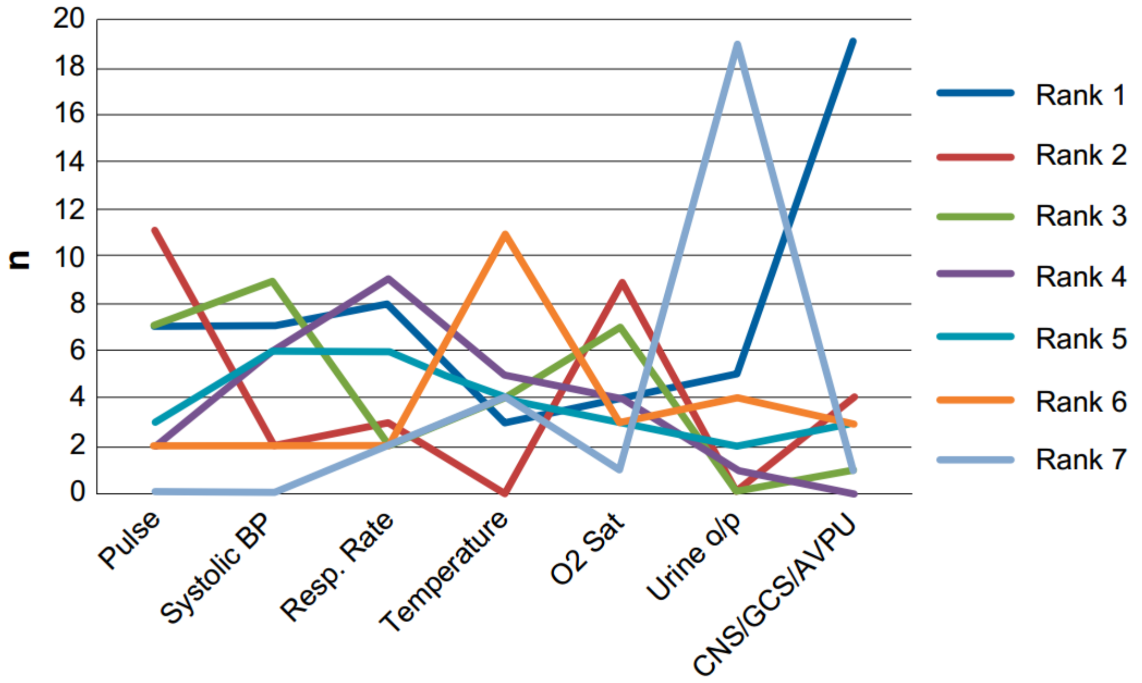

Figure 3. Number of participants ranking vital signs at various levels 1 to 7 (1 being the highest priority)

Variations between the decisions made with paper-based MEWS and eMEWS

To assess the impact of eMEWS prototype on decision making and to draw a comparison between the eMEWS and the paper-based MEWS, the participants were asked to describe the actions they would take for six patient scenarios using paper-based MEWS and eMEWS interface.

The variation of the actions described by the 71 participants using paper-based MEWS and using eMEWS prototype is investigated. The actions participants described for each case are analysed by text analysis methods. The repeated two- to seven-word phrases are counted for each patient grouped by paper-based MEWS and eMEWS as shown in Appendix III. The total number of repeated phrases at each length is then statistically analysed. This analysis is presented in Table 5. The degree of freedom for each case is 5 ($n = 6$). To assess the equality of two variances for each patient case, F-test is carried out. F-test was originally developed by Fisher in the 1920s (Lomax, 2007). In all cases the calculated F-values are smaller than the critical F-value [$F_{crit}(1,5)$ at $\alpha = 0.05$] and thus the null hypothesis (i.e. the variances are equal) is accepted. Thus, a matched one-tailed t-test can be carried out on the data. The P-values for all six patients are smaller than 0.05. This analysis has shown that there are significant differences between the actions described when using paper-based MEWS and eMEWS.

	Patient 1		Patient 2		Patient 3		Patient 4		Patient 5		Patient 6	
	Paper-based MEWS	**eMEWS**	**Paper-based MEWS**	**eMEWS**	**Paper-based MEWS**	**eMEWS**	**Paper-based MEWS**	**eMEWS**	**Paper-based MEWS**	**eMEWS**	**Paper-based MEWS**	**eMEWS**
Count of repeated 7 word phrases	1	0	2	0	0	0	0	0	0	0	0	0
Count of repeated 6 word phrases	2	1	4	1	0	0	0	0	1	0	0	2
Count of repeated 5 word phrases	6	3	7	5	1	3	1	1	2	0	1	5
Count of repeated 4 word phrases	14	10	11	10	5	10	8	9	3	0	7	14
Count of repeated 3 word phrases	30	30	25	23	22	27	27	30	10	6	25	26
Count of repeated 2 word phrases	30	30	30	30	30	30	30	30	28	22	30	30
df	5	5	5	5	5	5	5	5	5	5	5	5
Mean	13.833	12.333	13.1667	11.500	9.6667	11.6667	11.000	11.6667	7.3333	4.6667	10.5000	12.8333
S.D.	13.3329	14.1233	11.6175	12.3410	13.0333	13.5745	13.9140	14.5968	10.7269	8.8242	13.5167	12.7502
S.E.	5.4431	5.7658	4.7428	5.0382	5.3208	5.5418	5.6804	5.9591	4.3792	3.6025	5.5182	5.2052

Sample variance	177.7667	199.4667	134.9667	152.3000	169.8667	184.2667	193.6000	213.0667	115.0667	77.8667	182.7000	162.5667
F-test of variances	0.9025		0.8978		0.9310		0.9188		0.6787		0.9012	
F_{crit} (1,5) at a=0.05	1.6477	1.6477	1.6477	1.6477	1.6477	1.6477	1.6477	1.6477	1.6477	1.6477	1.6477	1.6477
Matched P-Value (1-tail)	0.0378		0.0054		0.0510		0.1177		0.0147		0.0454	
Note: df, Degree of Freedom; S.D., Standard Deviation; S.E., Standard Error												

Table 5. Analysis of the total number of repeated phrases with various lengths used by the healthcare providers for describing the actions they would take using paper-based Modified Early Warning Score (MEWS) and Electronic Modified Early Warning Scorecard (eMEWS)

DISCUSSION

This study identifies variations in healthcare providers' perceptions of critical reading ranges. Similarly, this study found that there also exists variation in prioritising the seven parameters associated with vital signs. It is noteworthy, however, that healthcare providers acknowledged the same highest and lowest priorities (CNS/GCS/AVPU and urine output, respectively). Yet a lack of consensus regarding the prioritisation of parameters between the highest and lowest was reported. These findings contribute not only to theory, but also to practice. The contribution to theory may be associated to identifying variations in healthcare providers' priorities of physiological parameters when visiting a patient. This, in turn, leads to variations in clinical assessment methods by healthcare providers. It contributes to practice by identifying that healthcare organisations should establish and implement baseline guidelines for assessing critical reading ranges which should be enforced within a healthcare environment. The findings of this paper reflect the fact that there are variations in the healthcare providers' perceptions of critical boundaries when visiting a patient. These variations may lead to further variations of care provided to patients with similar conditions when they need it.

On the basis that various perceptions of healthcare providers existed between critical reading ranges and the prioritisation of same, a comparison was drawn between the actions healthcare providers would take for a given patient using paper-based MEWS and using eMEWS. Interestingly, this research revealed significantly different actions performed by the healthcare providers based on the paper-based and electronic MEWS. The variation in actions is in line with previous findings of this paper. This further contributes to practice by informing healthcare organisations and vendors as to the performance of eMEWS. It demonstrates how a paper-based MEWS approach can be improved with the introduction of colour-coded charts, modified score ratings and the integration of CDSS. Furthermore, it also reflects that eMEWS may assist in addressing the variation amongst healthcare providers in prioritising vital signs and defining critical boundaries to a certain extent.

CONCLUSIONS

This paper attempts to identify the variations among healthcare practitioners' behaviour in defining critical threshold ranges for vital signs and prioritising vital sign parameters. The results show that there is a significant variation among healthcare practitioners' perception and behaviour in relation to prioritising vital sign parameters and their critical ranges. Based on this finding, decision making activities (from the actions considered) using MEWS and eMEWS are compared. This comparison revealed that actions performed using the two systems resulted in a significant difference in the activities undertaken and that eMEWS may be considered as an improvement to MEWS.

It is also important to acknowledge the limitations of the study. This study shows the impact that nursing experience may have on healthcare providers' perception of vital sign critical ranges. Yet an array of healthcare providers exists within a healthcare organization. Therefore, the first limitation of this study is that the data was primarily derived from nurses' input, i.e. about 79% (56 nurses of 71 total) of the participants in the study. Future research should examine the perceptions of other healthcare providers (i.e. doctors, surgeons) in far more detail to compare/contrast the results obtained from this study.

Second, the results of the study conducted on six patient cases show that there are significant differences among the actions they described using paper-based MEWS and eMEWS. However, this study does not establish the impact of eMEWS on the quality of the actions performed and associated care delivery. Thus, a thorough study needs to be conducted to evaluate the impact of eMEWS on the quality of the actions taken and the quality of care delivery.

Third, as outlined earlier, additional techniques can be examined to assist healthcare providers with their clinical decision making (i.e. pain rating). However, pain rating was not accounted for within this study. As a result, we call for future studies to examine pain rating variations between paper- and electronic-based solutions. This would provide richer insights into variations in decision making among healthcare providers. Despite its limitations, this paper makes a number of contributions to both the academic and practitioner communities.

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Appendix I. Modified Early Warning Scorecard (MEWS) parameters (based on the protocols deployed in the collaborator hospital)

Points Scored							
	3	**2**	**1**	**0**	**1**	**2**	**3**
Temperature; °C		<35.0	35.1-36	36.1-37.5	37.6-38.5	≥38.5	
Heart rate; beats min $^{-1}$	<40	41-50	51-55	56-100	101-110	111-139	>140
Systolic Blood Pressure; mmHg	<80	81-90	91-100	101-180	181-199	>200	
Respiratory Rate; breaths min $^{-1}$	<8			9-20	21-25	26-29	>30
SpO2; %	<85%	85-89%	90-94%	≥95%			
Canadian Neurological Scale (CNS)	Unresponsive	Responds to pain	Responds to Voice	Alert	New Agitation / Confusion		
Urine output; mL kg $^{-1}$ h $^{-1}$	<10	<30	<50				
Glasgow Coma Scale (GCS)				15	14	9-13	≤8

Appendix II. Modified Early Warning Scorecard (MEWS) protocol (based on the protocols deployed in the collaborator hospital)

MEWS SCORE ACTION	
MEWS SCORE	**Action**
1	Inform registered nurse for patient review.
2	Inform registered nurse for patient review. Increase frequency of observations to at least four hourly.
3 In any single parameter	Contact appropriate doctor for immediate review. Increase frequency of observations to hourly.
3 or more	Contact appropriate doctor for immediate review. Increase frequency of observations to hourly
If CNS score increases by 2 or more regardless of the other observations	Contact appropriate doctor for immediate review. Commence neurological observations.
CNS, Canadian Neurological Scale	

Appendix III. Number of times a phrase is repeated for each patient using paper-based Modified Early Warning Scorecard (MEWS) and Electronic Modified Early Warning Scorecard (eMEWS) and the total number of repeated phrases

	Patient1		Patient 2		Patient 3		Patient 4		Patient 5		Patient 6	
	Paper-based MEWS	eMEWS	Paper-based MEWS	eMEWS	Paper-based MEWS	eMEWS	Paper-based MEWS	eMEWS	Paper-based MEWS	eMEWS	Paper-based MEWS	eMEWS
Number of repeated seven-word phrases (e.g. increase frequency of observations to four hours)												
	2		2									
			2									
Count	1	0	2	0	0	0	0	0	0	0	0	0
Number of repeated six-word phrases (e.g. frequency of observations to 4 hours)												
	2	2	2	2					2			3
	2		2									3
			2									
			2									
Count	2	1	4	1	0	0	0	0	1	0	0	2
Number of repeated five-word phrases (e.g. increase observations to 1 hour)												
	2	2	2	4	6	3	4	2	2		4	3

	2	**2**	**2**	**2**		**2**			**2**			**3**
	2	**2**	**2**	**2**		**2**						**3**
	2		**2**	**2**								**3**
	2		**2**	**2**								**2**
	2		**2**									
			2									
Count	**6**	**3**	**7**	**5**	**1**	**3**	**1**	**1**	**2**	**0**	**1**	**5**
Number of repeated four-word phrases (e.g. elevate end of bed; pulse in 30 min; put patient on O_2)												
	3	**4**	**4**	**6**	**6**	**3**	**5**	**4**	**2**		**4**	**4**
	3	**4**	**3**	**4**	**6**	**3**	**4**	**3**	**2**		**4**	**3**
	2	**3**	**2**	**3**	**3**	**3**	**3**	**2**	**2**		**3**	**3**
	2	**2**	**2**	**2**	**2**	**2**	**2**	**2**			**2**	**3**
	2	**2**	**2**	**2**	**2**	**2**	**2**	**2**			**2**	**3**
	2	**2**	**2**	**2**		**2**	**2**	**2**			**2**	**3**
	2	**2**	**2**	**2**		**2**	**2**	**2**			**2**	**2**
	2	**2**	**2**	**2**		**2**	**2**	**2**				**2**
	2	**2**	**2**	**2**		**2**		**2**				**2**
	2	**2**	**2**	**2**		**2**						**2**
	2		**2**									**2**

	2											**2**
	2											**2**
	2											**2**
Count	**14**	**10**	**11**	**10**	**5**	**10**	**8**	**9**	**3**	**0**	**7**	**14**
Number of repeated three-word phrases (e.g. inform registered nurse; low O_2 sats; no action required)												
	7	6	8	8	11	6	9	6	2	4	6	8
	6	5	6	6	6	5	5	5	2	2	4	4
	4	4	4	6	6	5	4	5	2	2	4	4
	3	4	4	5	4	4	3	4	2	2	3	3
	3	4	4	4	3	4	3	4	2	2	3	3
	3	4	2	3	3	3	3	3	2	2	3	3
	3	4	2	3	2	3	3	3	2		3	3
	3	3	2	2	2	3	3	3	2		3	3
	2	3	2	2	2	3	2	3	2		3	3
	2	3	2	2	2	3	2	3	2		2	3
	2	3	2	2	2	2	2	2			2	3
	2	3	2	2	2	2	2	2			2	3
	2	2	2	2	2	2	2	2			2	3
	2	2	2	2	2	2	2	2			2	3

	2	2	2	2	2	2	2	2			2	2
	2	2	2	2	2	2	2	2			2	2
	2	2	2	2	2	2	2	2			2	2
	2	2	2	2	2	2	2	2			2	2
	2	2	2	2	2	2	2	2			2	2
	2	2	2	2	2	2	2	2			2	2
	2	2	2	2	2	2	2	2			2	2
	2	2	2	2	2	2	2	2			2	2
	2	2	2	2		2	2	2			2	2
	2	2	2			2	2	2			2	2
	2	2	2			2	2	2			2	2
	2	2				2	2	2				2
	2	2				2	2	2				
	2	2						2				
	2	2						2				
	2	2						2				
Count	**30**	**30**	**25**	**23**	**22**	**27**	**27**	**30**	**10**	**6**	**25**	**26**
Number of repeated two-word phrases (e.g. contact doctor; inform nurse; recheck vitals; immediate review)												
	12	8	12	8	23	8	24	9	6	17	22	11

	10	7	11	8	14	8	15	8	5	6	14	9
	9	7	10	8	13	7	12	8	5	4	9	9
	6	7	9	7	12	7	10	8	4	3	8	7
	6	7	7	7	11	7	8	8	3	3	6	7
	6	6	6	7	6	7	6	7	2	3	6	6
	6	6	6	6	4	6	6	7	2	2	5	6
	5	6	6	5	4	6	5	6	2	2	5	6
	5	6	5	5	4	6	5	6	2	2	4	5
	4	5	4	5	4	6	5	6	2	2	4	5
	4	5	4	4	4	5	4	6	2	2	4	4
	4	5	4	4	4	4	4	6	2	2	4	4
	3	4	4	4	3	4	4	6	2	2	4	4
	3	4	4	4	3	4	4	6	2	2	4	4
	3	4	4	3	3	4	4	6	2	2	4	4
	3	4	3	3	3	4	3	6	2	2	3	4
	3	4	3	3	3	4	3	5	2	2	3	4
	3	4	3	3	3	4	3	5	2	2	3	4
	3	4	3	3	3	4	3	5	2	2	3	4
	3	4	3	3	2	4	3	5	2	2	3	3

	3	4	3	3	2	4	3	4	2	2	3	3
	3	4	3	3	2	4	3	4	2	2	3	3
	3	4	3	3	2	4	3	4	2		3	3
	3	3	3	3	2	4	3	4	2		3	3
	3	3	3	3	2	3	3	4	2		3	3
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	2	3	3	3	2	3	2	3	2		3	3
	2	3	3	2	2	3	2	3	2		3	3
	2	3	2	2	2	3	2	3			2	3
	2	3	2	2	2	3	2	3			2	2
Count	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**28**	**22**	**30**	**30**