Research article

Workload involved in vital signs-based monitoring & responding to deteriorating patients: A single site experience from a regional New Zealand hospital

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ABSTRACT

Objective: This study aimed to quantify the workload involved in patient monitoring by vital signs and early warning scores (EWS), and the time spent by a rapid response team locally known as the Patient-at-Risk (PaR) team in responding to deteriorating patients.
Methods: The workload involved in the measurement and the documentation of vital signs and EWS was quantified by time and motion study using electronic stopwatch application in 167 complete sets of vital signs observations taken by nursing staff on general hospital wards at Taranaki Base Hospital, New Plymouth, New Zealand. The workload involved in responding to deteriorating patients was measured by the PaR team in real-time and recorded in an electronic logbook specifically designed for this purpose. Dependent variables were studied using analysis of variance (ANOVA), post hoc Tukey, Kruskal Wallis test, Mann-Whitney test and correlation tests.
Results: The mean time to measure and record a complete set of vital signs including interruptions was 4:18 (95% CI: 4:07–4:28) minutes. After excluding interruptions, the mean time taken to measure and record a set of vital signs was 3:24 (95% CI: 3:15–3:33) minutes. We found no statistical difference between the observer, location of the patient, staff characteristics or experience and patient characteristics. PaR nurses' mean time to provide rapid response was 47:36 (95% CI: 44:57–50:15) minutes. Significantly more time was spent on patients having severe degrees of deterioration (higher EWS) < 0.001. No statistical difference was observed between ward specialty, and nursing shifts.
Conclusions: Patient monitoring and response to deterioration consumed considerable time. Time spent in monitoring was not affected by independent and random factors studied; however, time spent on the response was greater when patients had higher degrees of deterioration.

1. Introduction

Rapid response systems (RRS) have evolved since the 1990s [1]. The RRS acts as an organisational surveillance system to enable the early detection (afferent component) and management (efferent component) of deteriorating patients [2] outside the intensive care unit (ICU) or critical care environment. The afferent component of RRS monitors patients' physiology using vital signs and early warning scores (EWS) – a score generated based on vital signs abnormalities – and is used as a tool to identify those patients who are at risk of deteriorating. The efferent component consists of a Rapid Response Team (RRT) that is activated when defined criteria based on vital signs and EWS monitoring are met to

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ensure a timely response and management of patients showing early signs of clinical deterioration.

Since 2016, New Zealand hospitals have adopted a standardised national approach to vital signs monitoring including heart rate, temperature, respiratory rate, blood pressure, oxygen requirement, oxygen saturation and level of consciousness to calculate the New Zealand EWS (NZEWS) and triage adult patients in general hospital wards [3]. The New Zealand Health Quality & Safety Commission (HQSC) implemented this approach through the Deteriorating Patient programme (2016–2021). They introduced a paper-based vital signs and NZEWS chart [4] which incorporates a colour-coded scheme for calculation of NZEWS. The programme sets out an escalation pathway with definitions of each level of escalation and an optimal timeframe to respond to each of these. It also provides a protocol for the recording of authorised modifications (exceptions) to the escalation pathway. According to the user guide for this vital signs chart [3], adult patients in general wards are required to undergo vital signs measurements and calculation of NZEWS every 4 h at a minimum, and the frequency of monitoring increases if the value of NZEWS is higher on one occasion. A value of NZEWS 10+ or any single vital sign derangement in the blue zone on the vital signs chart requires an immediate rapid response activation through a '777-call' which is the local equivalent of a Medical Emergency Team (MET) call. Lower values of NZEWS and less severe abnormalities in single vital signs require a medical or specialised nursing review by Patient-at-Risk (PaR) Nurses, a local equivalent of RRT.

The workload involved in vital signs-based patient monitoring is reported adequately; however, literature comprehensively examining the entire RRS care package per clinical event is lacking [5, 6]. Hence, our study aimed to quantify the workload involved in patient monitoring by vital signs and early warning scores (EWS), and the time spent by a rapid response team locally known as the Patient-at-Risk (PaR) team in responding to deteriorating patients.

2. Methods

2.1. Design and setting

We conducted a prospective observational time-and-motion study to measure the workload involved in patient monitoring using vital signs (afferent limb of RRS) by general ward nurses. The workload involved in responding to deteriorating patients (efferent limb of RRS) was quantified and reported in real-time by PaR nurses using an electronic PaR logbook at Taranaki Base Hospital, New Plymouth, New Zealand. The study was conducted between May 2020 and August 2021.

2.2. Ethics approval

Auckland University of Technology Ethics Committee (AUTEC) approved this research on 13 March 2019, under the application number of 19/37. All participants have provided informed consent.

2.3. Sample and recruitment

NZEWS charts [3, 7]are used throughout hospitals in New Zealand, predominantly either a paper-based or electronic monitoring chart. We conducted this study at Taranaki Base Hospital where paper based NZEWS charts are used. We selected general medical inpatient areas (Ward 4A, Ward 4B and Ward 2A). We recruited a total of 20 registered nurses as study participants on a voluntary basis after they had received the study information and understood the study purpose. We measured the time taken to complete a total of 172 sets of vital signs observations across all wards, out of which 167 were included in the analysis. Three observations were excluded due to the participant reporting they could

have been influenced by the presence of the researcher. Two observations were incomplete and were therefore also excluded.

A trained observer followed a standard operating procedure to record the time taken by the nursing staff to measure and record a complete set of vital signs. Each study participant (a general ward registered nurse) undertook between 1 and 15 complete sets of vital signs and NZEWS measurement and documentation. Time between entering and leaving the patient space was recorded as the total time taken to measure and record a set of vital signs and NZEWS. Interruptions were measured as laps on a multi-lap electronic stopwatch application 'Multi Timer Stop-Watch' developed and released by LemonClip available for Android phones at Google Play Applications Store [8]. This application was used to set up multiple timers/laps required to calculate the total time taken by each set of observations and separate timers/laps were run for various interruptions. All timers ran simultaneously. The time taken by the interruptions was subtracted from the total time taken by the observations to compute the time taken by vital signs and NZEWS without interruptions.

The study participants were not aware when the observations were timed and the observer was sitting in the adjacent patient bay behind a curtain from where the observer could see the participant but the participant could not see the observer. On the few occasions where the participant noticed the presence of the observer, the readings were excluded from the study as outlined above.

The PaR team recorded 4926 outreach calls from 1 May 2020 to 31 January 2021 where they measured the time spent per response in real-time and entered these values as minutes in an electronic logbook after each outreach call. This electronic logbook was specifically designed to measure and record the time spent by the PaR team while attending the outreach calls. We included 663 out of 4962 (13.5%) outreach calls in our study after applying the mandatory escalation criteria (a raised NZEWS value of five or higher or single vital sign value in blue-colour zone on NZEWS chart). Using these two criteria ensures we have selected the cases where the PaR team was primarily involved in delivering rapid responses to deteriorating patients.

2.4. Calculation of early warning score

According to NZEWS calculation method, the normal range of values for each vital sign is represented by white colour and extremely abnormal values are represented by blue colour. Mild, moderate and severely abnormal values for each vital sign are represented as yellow, orange and red-coloured zones on the NZEWS chart, respectively. This enables nursing staff to calculate NZEWS easily where they score 0 for white, 1 for yellow, 2 for orange and 3 for red. Any single vital sign value reaching the blue-coloured zone on NZEWS mandates a rapid response trigger irrespective of the total early warning score as shown in Figure 1, which combines the aggregate scoring criteria that is the key driver of the UK's National EWS [9] and the single parameter calling criteria advocated by Lee et al. [10].

2.5. Data management and statistical analysis

The data were collected on a Microsoft Excel file. The MS Excel file was imported into IBM SPSS 27 and saved as an SPSS data file after defining the variable characteristics. The variables were cross-checked against the original Excel files. Interruptions were subtracted from the total time to measure vital signs using the 'compute variable' function in SPSS. A Kolmogorov-Smirnov test was used to assess data normality. For descriptive statistics frequency, mean and standard deviations were reported. In inferential statistics mean time per vital sign observations (total after excluding one as well as both types of interruptions) were compared between participants, patient disposition, ethnicity, and study sessions. The data on time spent per response was studied for different
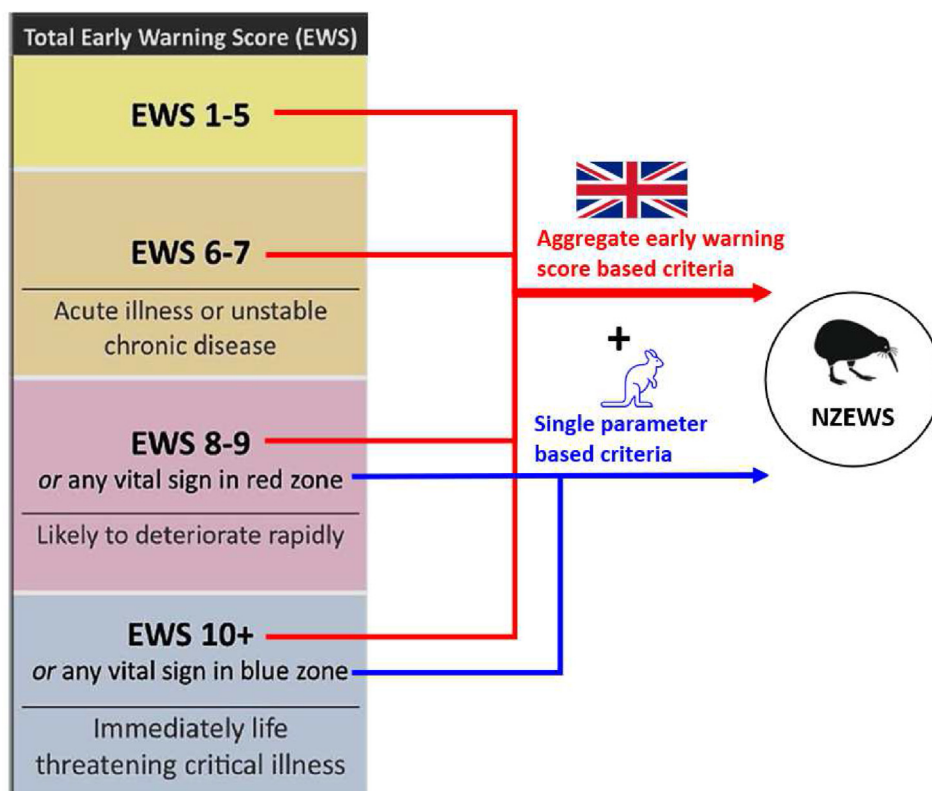
Figure 1. A schematic representation of how aggregate scoring and single parameter-based 'Calling Criteria' are adapted by the NZEWS [4].

dependent variables using analysis of variance, post hoc, Kruskal Wallis test, Mann-Whitney test, and correlation.

2.6. Ethics approval

The study was approved by Taranaki District Health on 6 January 2021.

3. Results

In our study, the mean time taken by nursing staff to measure and record a complete set of vital signs (including any interruptions) was 4.30 (95% CI: 4.12–4.47) minutes. After excluding all interruptions, the mean time taken to measure and record a complete set of vital signs was 3.40

(95% CI: 3.25–3.55) minutes. As shown in Table 1 none of the studied parameters (location of ward, patient disposition, patient ethnicity and staff experience/seniority defined by number of years in the nursing profession) was found to significantly affect these results.

The time spent per rapid response presented in this study is based on 663 rapid responses to deteriorating patients in general hospital wards outside the intensive care unit, during the study period performed by PaR nurses. We evaluated 4926 activities performed by the PaR nurses during this period, for which they recorded the time spent per activity in an electronic application specifically designed to track the workload involved in PaR nurses' activities. However, we included 663 (13.5% of the total) PaR activities which fitted the criteria for a rapid response provided to deteriorating patients on general wards.

Table 1. Time taken to measure and record vital signs and EWS (in minutes).

Parameter		n = 167	Total time taken		Time excluding non-vital signs related interruptions		Time excluding vital and non-vital interruptions	
			Mean ± SD	p	Mean ± SD	p	Mean ± D	p
Location	- Ward 4A	84	4.35 ± 1.10	0.549	3.76 ± 0.91	0.386	3.47 ± 0.93	0.394
	- Ward 2A	83	4.24 ± 1.17		3.63 ± 1.00		3.34 ± 1.01	
Patient disposition	-Ward patient	119	4.33 ± 1.08	0.566	3.70 ± 0.91	0.805	3.41 ± 0.94	0.852
	- Outlier‡	48	4.21 ± 1.27		3.66 ± 1.03		3.38 ± 1.04	
Patient Ethnicity	- Maori	46	4.36 ± 1.31	0.721	3.79 ± 1.13	0.693	3.50 ± 1.16	0.708
	- NZ Europeans	106	4.29 ± 1.01		3.67 ± 0.84		3.37 ± 0.85	
	- Others	15	4.09 ± 1.42		3.59 ± 1.16		3.31 ± 1.16	
Staff experience/ seniority	<2 years	71	4.34 ± 1.11	0.651	3.73 ± 0.94	0.530	3.45 ± 0.88	0.505
	3-10 years	65	4.19 ± 1.08		3.59 ± 0.88		3.30 ± 0.88	
	>10 years	31	4.39 ± 1.30		3.81 ± 1.14		3.52 ± 1.17	

*One-way ANOVA test was used.
+ p-value less than 0.05 was considered significant.
‡Outlier patients are generally more acute patients who stay briefly and require more frequent observations.

Table 2. Time spent per response by PaR nurses to deteriorating patients (in minutes).

Parameters		n	Mean ± SD	p
Nursing shift	AM Shift (0645–1515 h)	182	48.99 ± 36.36	0.697
	PM Shift (1445-2315 h)	281	47.84 ± 33.93	
	Night Shift (2245-0715 h)	200	46.01 ± 34.86	
Location attended	Emergency	83	49.81 ± 36.72	0.050
	Medical floors	339	44.03 ± 30.86	
	Surgical floors	194	51.28 ± 37.28	
	Other areas	47	54.32 ± 45.20	
Severity of deterioration	EWS 6-7	294	41.47 ± 29.24	<0.001
	EWS 8-9	115	52.22 ± 38.09	
	EWS 10 †	254	52.61 ± 38.17	
Total		663	47.60 ± 34.86	

*One-way ANOVA test was used.

+ p-value less than 0.05 was considered significant

†This is a 777-call/medical emergency team call.

Table 3. Correlation between Time Spent by PaR nurses (in minutes) and severity of deteriorating patients.

Severity of deterioration	n = 663	Mean ± SD	Correlation	
			Rho	p
EWS 6-7	294	41.47 ± 29.32		
EWS 8-9		52.22 ± 38.09	**0.139**	**0.00***
EWS 10 or 777	254	52.61 ± 38.17		

*Spearman Rho test for correlation was used.

+ p-value less than 0.05 was considered significant

The average time spent by PaR nurses in these rapid responses (n = 663) was 47.60 (95% CI: 44.95–50.26) minutes. Time per response was studied against the location/ward, responder (PaR nurse) and HQSC criteria for escalations based on the EWS score as shown in 2.

Escalation criteria were found to have a significant association with time spent per response as shown in Table 3. Post hoc the Tukey HSD test was also applied to evaluate the association between time spent per response and severity of deterioration. The difference between time spent on EWS 8-9 calls and EWS 10-777 calls was not significant (p = 0.994), whereas the time spent on 'EWS 8-9' (p = 0.013) and EWS 10 or 777 calls (p = 0.001) was significantly higher in comparison to the time spent on 'EWS 6-7' calls. Also, a weak positive correlation was observed between severity of deteriorating patients (EWS scores) and time spent by PaR nurses (Rho = 0.139 and p < 0.001) which means the time spent per response tends to gradually increase with increasing EWS scores.

4. Discussion

This is the first study of its kind that reports the workload involved across the entire spectrum of RRS activities as the previously reported studies have only measured the workload involved in the efferent limb of the RRS – measuring and recording vital signs and EWS [11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23]. Therefore, our study offers to extend the body of knowledge particularly by adding the quantification of workload involved in responding to deteriorating patients by a rapid response team or critical care outreach team. Our findings are applicable to adult patients in general hospital wards where paper based vital signs and EWS charts are used with manual measurement and recording of these parameters to enable early recognition and response/treatment of deteriorating patients. We found that measurement and recording of a complete set of vital signs (heart rate, temperature, blood pressure, respiratory rate, oxygen requirement, oxygen saturation, and level of consciousness) and manual calculation of New Zealand EWS was independent of the factors studied as shown in Table 1. We found that the

average time spent per rapid response was over 47 min, and again it was not affected by the ward location of rapid response or the responder providing this rapid response as shown in Table 2. Severity of deterioration, as defined by the graded escalation criteria based on NZEWS was found to have significant association with time spent per response <0.001. The time spent per response was positively correlated with NZEWS values as shown in Table 3.

Studies reporting the workload involved in measuring and recording vital signs and EWS are mentioned below with a summary of their findings and how they relate to our findings. Dall'Ora et al. [11] conducted a time-and-motion study in four hospitals in the United Kingdom (UK) using a comparable set of vital signs and found that average estimated time to measure and record a set of vital signs and EWS was 3.75 (95% CI = 3.53–3.97) minutes. They found no substantial differences by hospital, ward, or nurse characteristics, despite different systems for recording observations being used across the four hospitals. McGrath et al. (2019) [24] reported a before and after study from the USA upon implementing an electronic system to track vital signs, EWS and trigger rapid responses. This study found that the mean time to measure and record the vital signs and EWS was 2.98 min for the manual system and 2.15 min for the electronic system. Level of consciousness was not assessed and recorded in their study. Wong et al. (2017) [13] also performed a before and after study in the UK and reported a mean time of 3.58 min to undertake a complete set of vital signs while using a manual system and 2.50 min while using an electronic system. They reported the time to view a paper chart (0.3 min) and electronic chart (0.21 min) separately. Kimura et al. (2016) [14] in their descriptive observational study from Japan reported a significantly lower time to measure and record vital signs and EWS using an electronic system and transfer of information using radio-frequency identification (RFID) readers. They reported 1.47 ± 0.55 min per person at the patient trolley or cart and 1.27 ± 0.62 min per person at the bedside. Bellomo et al. (2012) [15] conducted a large multi-national before and after controlled trial, including ten hospitals from five countries. They reported a reduction in the time required for collection and recording of data, with the introduction of continuous monitoring. The time required to complete and record a set of vital signs decreased from on average 4.10 ± 1.30 min to 2.50 ± 0.50 min which was statistically significant (p < 0.0001). Wager et al. (2010) [16] conducted an observational descriptive study in a single hospital in the USA to report a mean time difference between the time vital signs were taken and when the data were recorded in the patient's record. They reported a mean of 1.24 ± 2.17 min with paper records, 9.15 ± 7.25 min with Computer on Wheels (CoWs). Clarke (2006) [18] performed a descriptive observational study at a community hospital in the USA to report a mean time of 5.80 ± 3.72 min to measure and record vital signs. Zeitz (2005) and Zeitz and McCutcheon (2006) [17, 19] undertook a descriptive observational study on 81 patients in two surgical units of two different hospitals in Australia to report a mean time of 5.80 ± 2.56 min to take vital signs and any other associated activities related to the vital signs. The vital signs included in their study were limited to temperature, heart rate, blood pressure and respiratory rate only. Travers (1999) [21] conducted an observational time-and-motion studies on 16 nurses (participants) working in an emergency department of a general hospital in the USA reporting a mean time of 4 (range 2–11) minutes to measure and record vital signs at the time of patient triage. Ito et al. (1997) [22] reported the earliest study on workload involved in vital signs monitoring. They conducted a pre and post study analysis with time-and-motion methodology on 23 nurses working day shifts at a radiology ward of a public hospital in Japan. The mean time required to measure vital signs and to record those was reduced from 2.02 min in the manual process to 0.90 min in the electronic process.

Our findings on the quantification of the workload involved in patient monitoring through vital signs and NZEWS are consistent with the recent studies described above. There are no obvious differences to note in the average time spent per single set of vital signs and NZEWS apart from what is plausible with the use of different equipment. We found a few

studies [23, 25, 26, 27] that estimated the workload involved in measuring vital signs without reporting mean time per set of vital signs, hence we are unable to make any comparison with them.

Most of the studies described above have not reported the procedure of EWS calculation. Our study is based the NZEWS chart, which is used nationally within New Zealand and provides a standardised method for calculation of EWS using the numerical weighting and colour coding system [3] as outlined above.

Though the primary aim of our study was to quantify the workload involved in the afferent and afferent limbs of RRS, we have extrapolated the findings to compute the workload contributed particularly by the afferent limb of RRS to the overall nursing workload in general hospital ward settings. We computed the workload involved in patient monitoring based on the 4-hourly vital signs observations which is minimal frequency of monitoring required by the NZEWS national policy [28]. If no patient is required to have a higher frequency of vital signs observations, based on our results, 8.51 (CI: 8.14-8.88) fulltime equivalents (FTEs) of nursing time would have been used in a 24-hour cycle in a hospital of approximately 200 beds when all interruptions are removed. When we compute the same workload per 24 h considering the observed interruptions in our study, we estimate that 4-hourly vital signs observations would require 10.74 (CI 10.30–11.17) FTEs of nursing time every day. Because these estimates consider all patients in a stable physiological state who require 4-hourly observations, actual FTEs involved must be higher than these estimates. This is first study which attempts to quantify the workload involved in the vital signs-based patient monitoring in a system where nursing staff manually undertake vital signs observations and record in a paper-based vital signs charts. These estimates provide a guidance into the workforce implications of the patient monitoring in general wards, as well as provide evidence-based data to calculate the potential savings when the hospitals move from a manual to an electronic vital signs-based patient monitoring. Such an electronic monitoring using wearable technology [29, 30] not only promises to cut the costs or in other words workload for nursing staff, but also enables many other innovative applications for the detection of deteriorating patients [31, 32].

The findings of the workload involved in responding to deteriorating patients by PaR nurses can be extrapolated to quantify the optimal workforce requirements for rapid response teams in a general hospital. Our findings on workload involved in the afferent and efferent components of RRS should be applicable to New Zealand hospitals and possibly overseas where vital signs and EWS are used to recognise and to respond to deteriorating patients. These results also provide a baseline for future comparisons when an electronic system is adopted for measuring and recording vital signs, and documenting rapid responses, especially when such end-to-end systems exist [33]. The main limitation of this study is, our findings are based on paper-based vital signs and EWS charts to drive the afferent RRS, as we did not have comparable findings on the workload involved in these activities through an electronic system. A comparison is presented by some of the studies included in a recent systematic review [12].

5. Conclusions

Patient monitoring of (afferent) and responding to (efferent) deteriorations consume considerable clinician time which is not well reported using an end-to-end rapid response system approach. Time spent in monitoring is not affected by independent and random factors, which is consistent with the literature. We found that time spent in responding to escalations was greater when patients had a higher level of deterioration which is plausible; however, there is no literature available to draw a comparison on this. We advocate that the study of the workload involved in RRS using a whole system approach should be applied, studied, and reported for the various models of rapid response teams, and the findings of such studies should inform policy on patient monitoring and workforce strategy.

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