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Special Article

Make vital signs great again – A call for action

John Kellett [a,*], Frank Sebat [b]

[a] Department of Emergency Medicine, Hospital of South West Jutland, Esbjerg, Denmark
[b] Faculty Internal Medicine, Mercy Medical Center, Redding, CA, USA

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ABSTRACT

Vital signs are the simplest, cheapest and probably the most important information gathered on patients in hospital. In this narrative review we present a large amount of evidence that vital signs are currently little valued, not regularly or accurately recorded, and frequently not acted on appropriately. It is probable that few hospitals would keep their accreditation with regulatory bodies if they collected and acted on their laboratory results in the same way that they collect and act on vital signs. Professional societies and regulatory bodies need to address this issue: if vital signs were more accurately and frequently measured, and acted on promptly and appropriately hospital care would be safer, better and cheaper.

1. Introduction

Numerous studies have reported that the deterioration of patients is often missed [1–4] even though it is usually preceded by worsening vital signs [1,5–16]. Many medical tragedies result from either poor vital sign recording or abnormal vital signs not being noticed or responded to appropriately [17–20]. Poor clinical monitoring has been implicated in 31% of preventable deaths in hospitals in England [21], and several studies and systematic reviews have highlighted this issue as a worldwide problem [22–24].

Vital signs are the simplest, cheapest and probably the most important information gathered on patients in hospital, and the major components of early warning scores and other "track and trigger" systems [25] for the detection of clinical deterioration from sepsis and other causes, which are now part of routine practice in several countries [25–28]. Their ability to predict outcome, monitor clinical course and indicate the need for treatment is firmly established and cannot be overstated. In a study of one million vital signs patients with one abnormal value had an in-hospital mortality of 0.9%, whereas the mortality rate of those with three abnormal values was 24% [29]. These and the numerous other results cited above notwithstanding, concerns have consistently been raised that nurses do not regard vital sign measurement and reporting as a priority and often neglect them [30–33]. In contrast laboratory tests are highly valued by nursing staff; 80% of nurses consider that they should be performed daily on all patients in hospital even though there is no evidence that such a policy is of clinical benefit [34].

The routine recording of vital signs has become a task oriented ritualistic practice [35,36] often delegated to healthcare assistants [36]. As a result recordings are often absent or infrequent [36–39] and performed without the required skill and knowledge [35,36]. Many nurses do not know that a drop in blood pressure is a late and not an early sign of deterioration, which is usually preceded by a compensatory increase in pulse and respiratory rate [40–42]. It is, therefore, not surprising that the importance of increased respiratory rate as a key indicator of deterioration is often not appreciated [30,41,43] and why one study found that a fall in blood pressure was the most common reason to call a medical emergency team and respiratory rate never was [43]. Doctors also have been found to have inadequate knowledge of vital signs and critical care [44].

2. History of vital signs

The four classic vital signs are respiratory rate, body temperature, pulse rate and blood pressure were introduced into clinical practice between 1860 and 1900. Although ancient physicians were aware of the association between fever and rapid heart rates, it was not until the mid-nineteenth century that the measurement of these vital signs first became part of routine medical practice. In 1863 John Davy (1790–1868), while Inspector General of Army Hospitals in the West Indies, noticed and intimate connection between pulse, temperature and respiratory rate. At about the same time, Joseph Jones (1833–1896), while serving as a surgeon with the Confederacy during the American Civil War, included temperature, pulse and respirations together in his case reports on malaria. In May 1866 Edward Seguin and William Draper, while interns at New York Hospital, published an Article in the Chicago Medical Journal reporting three cases of pneumonia that included a chart of "Vital Signs" used at the bedside to make the daily record of temperature, pulse-beats and respirations [45]. By the mid-19th century, the medical thermometer was still a foot long (30.28 cm) and took as

* Corresponding author at: Ballinaclough, Nenagh, Ireland.
E-mail address: jgkellett@eircom.net (J. Kellett).

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long as twenty minutes to take an accurate temperature reading; between 1866 and 1867 Sir Thomas Clifford Allbutt (1836–1925) designed a much more portable, six inches long medical thermometer that took only five minutes to record a patient's temperature [46]. At the same time railways had increased the demand for pocket watches to time the accurate departures and arrival of trains [47]. As a result affordable pocket watches with second hands became widely available and allowed every physician, from hospital consultants to country doctors, to accurately record the pulse rate at the bedside.

Blood pressure was adopted as a vital sign more recently. The easy-to-use cuff-based version of the mercury sphygmomanometer was invented by Scipione Riva Rocci (1863–1937) an Italian internist, pathologist and paediatrician [48]. The American neurosurgeon, Harvey Cushing (1869–1939) visited him at Pavia in 1901 and made drawings of his device [49]. On his return to the US he made a similar device and used it successfully in Johns Hopkins Hospital, most notably in intracranial surgery [50]. In 1905 Dr. Nikolai Korotkoff, a Russian physician working at the Imperial Medical Academy in St Petersburg, described the sounds associated with systolic and diastolic blood pressure [51]. The use of these Korotkoff sounds and other technical improvements allowed Cushing to play a major role in popularizing Riva Rocci's mercury sphygmomanometer [49]. Nevertheless, the adoption of blood pressure as a vital sign was slow, and it was not until 1970 that it was included in most hospital vital sign charts [45].

Despite their long use, the medical profession has carried out very little research into vital signs, has been reluctant to recognize and utilize their value, slow to adopt new technology that would enhance their collection and usefulness, and cared little about their accuracy, precision and how frequently they were measured. Until recently the largest study of respiratory rate was performed by Hutchinson in 1846 [52] and the largest studies on fever remain those performed by Wunderlich in the nineteenth century [53]. Amazingly the ominous significance of low temperatures has only recently been appreciated [54,55], and the mortality risk associated with transient hypotension only reported for the first time in 2006 [56]. It was not until 1966 that the prognostic significance of the relationship between a high heart rate and low blood pressure (i.e. the Shock Index) was recognized [57], and not until 1997 that combining vital signs into early warning scores was proposed [14]. It has only just become apparent that a fast resting heart rate is a risk factor for cardiovascular mortality [58–63].

3. How well are vital signs measured?

Concerns over the poor documentation of vital signs correctly are well founded. Although taking a radial pulse is considered to be an essential clinical skill [64] there is little practice-based evidence on how well it is measured. The only practice-based evidence studies on the accuracy of heart rate measured on unselected acutely ill medical patients showed a poor correlation between heart rate recorded by nurses and the actual heart rate recorded by ECG [65,66]. Oliver et al. reviewed 9075 vital sign recordings on 1000 hospitalized children and found only 25% had blood pressure measured and only 53% had a full set of measurements recorded [67]. A cross-sectional study of 43,232 visits to Veteran's Administration emergency departments found blood pressure was not obtained in 14.4%, respiratory rate in 15.1%, pulse in 14.4%, temperature in 16.8% and oxygen saturation in 33.0% [68]. A quasi-experimental study in Holland found only 70% of nurses complied with the protocol that required vital signs to be measured 3 times per day [69]. A retrospective audit in Australia of patient records following major surgery found only 17% had complete documentation of vital signs; respiratory rate was the most commonly omitted observation, being undocumented in 15.4% of records [70]. In a Canadian study nearly all (99.6%) of 18,853 acutely ill medical patients admitted to hospital had all four vital signs, their oxygen saturation and the use of supplemental oxygen recorded on admission [71]. Although the hospital's policy was for every patient to have their vital signs recorded six hourly, only 82% had a complete second set of observations, and only 66% had a third set recorded. The 7717 patients who never had a third set recorded were significantly younger, sicker and had a longer length of hospital stay the other patients. Although less of these patients had cancer or a stroke they were also more likely to die in hospital (odds ratio 1.16, 95% CI 1.04–1.29, Chi-square 7.1, p 0.008). In a similar study of 18,827 surgical patients admitted to the same hospital, it had been hoped to analyze changes in vital signs at six hourly intervals for up to between 48 and 72 h after admission [72]. This, however, turned out not to be possible. Although the number of vital signs recorded per day was far more than anticipated (i.e. 27 per patient), they were not entered into the hospital electronic medical record system at the same time. It is probable that many patients had their vital signs measured by clinical staff and temporarily recorded on paper, and only entered into the computer system at a convenient later time, such as at the end of a shift. Moreover, many more sets of vital signs might have been measured, but never recorded in the electronic system. Other researchers have also noted that the use of electronic health records results in the delayed and inaccurate recording of vital signs [73].

Some studies have shown a higher collection rate of vital signs, with some reporting collection rates of 85% [74] to 90% [75]. The electronic collection of manually recorded respiratory rate, arterial oxygen saturation, use of supplementation oxygen, pulse rate, systolic blood pressure, level of consciousness, and body temperature has been mandatory in Copenhagen since 2013. A study of 2,835,331 of these records found only 271,103 (10%) had one or more missing values; body temperature, the most frequently omitted variable, was missing in 79,991 (66%) of them [75]. However, both pulse rate and systolic blood pressure records, which were read from automatic or semi-automatic devices, showed a preference for numbers divisible by 10. If the readings from devices had been entered unmodified into the electronic record these digit preferences should not have occurred. Moreover, pulse rates were biased to values below 91 beats per minute, a value that would have triggered more nursing tasks and other clinical interventions. These findings suggest that nurses may have manipulated vital sign values in order to make the patients appear less sick, possibly in an attempt to reduce their workload. When vital signs are used to calculate early warning scores similar errors that bias values toward normal are made, with as few as 20% of early warning scores being correctly calculated [69,76].

Vital sign measurements may be further limited by significant inter-observer variability, but only a few studies have addressed this issue. Respiratory rate measurements [77–79] have been reported to have an inter-observer variability of up to 6 breaths per minute, and Edmonds et al. reported an expected range of agreement between observers of ± 10.6 beats per minute for heart rate, ± 6.2 breaths per minute for respiratory rate and ± 24.2 mm Hg for systolic blood pressure [80].

4. How often should vital signs be measured?

Although around 40% of critical vital sign findings occur early within 48 h of admission, another 40% occur much later and more than five days after admission [29]. Therefore, ongoing monitoring of the patient is essential. There is, however, no consensus on how often vital signs observations should be made [35,81]. Outside of intensive care units, clinical practice currently relies on the periodic, manual observation of vital signs, which typically occurs every four to six hours in most hospital wards in North America and less frequently elsewhere [81]. Present recommendations vary widely with little evidence to support them and are based on compromises between patient safety and local work load issues [23]. The frequency of vital signs monitoring should be determined based on a patient-centred approach to care [82,83]. Current practices of vital signs monitoring, based on tradition rather than evidence, may place unrealistic demands on nurses [31,41,84]. When nurses are taking vital signs they are frequently distracted or interrupted [36], and demanding excessive vital signs monitoring will affect how nurses

prioritize their workload and compromise their ability to closely monitor more acutely ill patients [84,85]. Despite these concerns the UK Royal College of Physicians recommends a full vital set of vital signs every 12 h in all patients, a minimum of every 6 h if there is any vital sign abnormality, and either hourly or continuous monitoring for severely ill patients [28]. Although the optimal monitoring frequency for low risk populations remains unknown, Petersen et al. found no benefit from monitoring vital signs three times a day over twice a day in stable patients with normal vital signs [86]. These results should be interpreted with caution. Most failure to detect clinical deterioration occurs most often on general wards, and if vital signs are not measured correctly in the emergency department patients that require intensive care may be admitted to general wards in error. In a study that compared the mandatory measurement of an early warning score three times daily with its measurement "when clinically indicated", nurses called the patient's physician ten times more often and the medical emergency time twice as often. These findings suggest that vital signs determination three times daily results in far better and prompter detection of physiological abnormalities and clinical deterioration [69].

5. Does everyone know what they are doing?

The increasing automation of vital signs and pulse oximetry monitoring may have resulted in nurses spending less time performing quick checks of the respiratory rate [87] and on visual observations such as the work of breathing and accessory muscle use [41]. The poor bedside assessment of patients may also be consequence of broken or poorly maintained devices or limited access to equipment and their accessories [35,37,88]. Moreover, current technology has limitations, which are often not appreciated. Once systolic blood pressure drops below 100 mm Hg, it may be difficult to detect manually both by auscultation and palpation, and detection by automated devices also becomes unreliable [89]. Indeed, once the pulse can no longer be felt at the wrist the systolic blood pressure cannot be measured accurately non-invasively [90]. In such a situation, in order to determine a patient's true clinical state it is essential to touch and feel the patient [91], examine their skin for clamminess and coldness and listen to what they are saying [92]. Although pulse oximeters are now used frequently to assess patients many doctors and nurse lack knowledge on their basic principles, and make serious errors interpreting their readings. There is a common misconception that oximetry can replace respiratory rate monitoring [41,93,94]. Oxygen saturation has not been demonstrated to be a specific indicator of serious illness [17,95] and may appear to be normal during the early phase of deterioration, due to a rise in respiratory rate to compensate for the inadequacy of oxygen delivery. The most important of limitation of oximetry is the false reassurance of "a normal" oxygen saturation in a sedated patient receiving high concentrations of supplemental oxygen. In addition, there is a potential time delay between the onset of any hypoxic event and its detection by oximetry [96]. Respiratory rate measurements correlate poorly with oxygen saturation measurements and do not screen reliably for low oxygen saturations; patients with low oxygen saturation do not usually exhibit increased respiratory rate. Similarly, increased respiratory rate is unlikely to reflect oxygen de-saturation [97].

6. Why do nurses not measure respiratory rate?

Respiratory rate is a powerful predictor of disease severity and of a poor outcome [77,98] and, since it is increased by both hypoxia and metabolic acidosis, it can indicate severe derangement in many body systems [94]. An increased rate is often the first sign of sepsis, shock and respiratory insufficiency and a reduced rate warns of narcotic and sedative overdose. The National Institute for Clinical Excellence (NICE) considers respiratory rate to be the most sensitive marker of a deteriorating patient and the first observation to indicate a problem [99]. It is well established as a valuable early independent predictor of mortality, intensive care unit admission and cardiac arrest across a variety of conditions among hospitalized adults [14,17,26,42,77,94,95,98,100–106], assists in the detection of sepsis [107] and myocardial infarction [108], and the first vital sign to deteriorate in dying patients [109,110]. It is also an integral component of many risk prediction scores such as early warning scores [14,111,112] and is one of the clinical criteria for determining the stability for discharge [113,114].

Despite respiratory rate's well established clinical value nurses often fail to measure it [35,115]. It is the vital sign least often recorded and most commonly omitted from hospital documentation [71,116–118], being recorded less than 50% of the time by nursing staff [35]. Respiratory rate has been called the vexatious clinical sign because it requires patience and diligence to measure accurately [119]. Both formal and "spot" assessments of respiratory rate by doctors are extremely inaccurate and imprecise [120]. Many studies have demonstrated respiratory rates obtained in practice are inaccurate, lacking both reliability and reproducibility in a variety of health care settings [78,119,121]. Emergency department triage nurses' have been reported to be poor at detecting abnormally fast and slow respiratory rates [119]. In another study clinical staff assessed respiratory rate by just looking at the patient: it is, therefore, not surprising that they had little confidence in the accuracy of the respiratory rate measurements recorded in their observation charts, believing many were estimated, or even fabricated [122]. The reasons why nurses do not monitor respiratory rate are complex and include time pressures and work interruptions. However, they also include the lack of value placed on the respiratory rate by nursing staff [35]. These widespread misconceptions and lack of knowledge need to be and can be addressed [123].

It has been suggested that the ideal respiratory monitor should unobtrusively provide continuous information on respiratory rate and depth, as well as the degree of gas exchange taking place [121]. Although currently there is no widely used convenient, cheap, reliable method of doing any of these things, respiratory rate monitoring devices are in development and may soon be available for widespread use [124]. Measurement techniques can intrinsically alter breathing dynamics and the respiratory rate itself, thus influencing the validity of their results [125]. Casual observations or "spot" checks are known to produce unreliable assessments of respiratory rate [126]. However, a simple software "app" is now available that may improve the speed and accuracy of respiratory rate measurement at the bedside [127]. Measurements by nursing staff have been reported to correlate poorly with those of prototype machine systems and, unlike machine measurements, did not predict patient outcome [66]. In one study nurses only detected tachypnea with a sensitivity of 23%, compared to a sensitivity of 91% for an electronic sensor [128]. In a study of 36,966 hospitalisations the respiratory rate recordings were not normally distributed, but skewed with values clustered around the even numbers of 18 and 20 breaths per minute, whereas heart rates had a normal distribution [129]. Similar results, with a clustering of results around even numbers such as 18 and 20 breaths per minute have been noted by others [66,119,126,129–131]. This indicates that ward staff either measure respiratory rates over a shorter time period than one minute and multiply the results or simply estimate respiratory rates based on the general appearance of the patient. Both explanations have been suggested [126,130], and may explain why manually measured respiratory rates correlate poorly with those of devices.

7. What are the alternatives to the classic vital signs?

There is no doubt that experienced clinicians can suspect serious illness just by looking at the patient [132]. However, it is not clear if this gestalt is gained intuitively after years of experience, or whether it is something that can be quickly and cheaply taught to almost anyone within a short period of time. Some of it might be captured in a recently reported "nurse worried" score [133], but this has yet to be independently validated and may not be applicable to all clinical grades.

Paramedics, for example, may not be able to safely decide which patients do not need ambulance transport or emergency department care [134]. In one emergency department when patients were evaluated as "not seriously ill" by medical staff the measurement of all vital signs tended to be skipped [135]. However in another study initial triage decisions were downgraded (decreased in urgency) in 2.4% of patients, and upgraded (increased in urgency) in 5.5% of patients after vital signs were measured [136].

The first signs of illness are almost always subjective changes in the patient's sense of well-being, that may well be sensed by an experienced nurse before there are any changes in vital signs. Moreover, several factors need to be taken into account when interpreting vital signs since they are strongly influenced by pain, breathlessness, the emotional state of the patient and medication. Pain [137], breathlessness [138], mental status [139], functional status and mobility [140] have all been proposed as additional vital signs. Although some of these parameters may indicate that deterioration is imminent, pain is a poor predictor of outcome, and its promotion as a vital sign may well have contributed to the current "opiod crisis" in North America [141]. With the exception of coma, serious illness that requires immediate action is unlikely to be present without any classic vital sign abnormality, and is unlikely NOT to be present when several vital signs are abnormal [29]. Therefore, the accurate regular measurement and correct interpretation and response to the classic vital signs must always remain as essential requirements for safe medical care.

8. The challenges and opportunities of new technology

In the near future, wearable devices are likely to become available that will provide continuous streams of vital-sign information and their trends on all patients. This will generate massive requirements for both their storage and analysis, with potential dangers associated with the availability of too much information [142] such as information overload, false alarms, alarm fatigue etc. Since it is not known how often, to what extent, and over what time frame continuously measured vital signs change, and what the implications of those changes are, it is impossible to know without research studies how to respond to them or develop rational management protocols [143]. Recent studies have suggested that trends in vital signs will be of considerable prognostic value: it remains to be seen if this will translate into better outcomes [105,144,145]. Disappointingly, a recent randomized study found that there was no benefit for high risk surgical patients from continuous monitoring over intermittent monitoring [146]. In contrast other studies have revealed a significant decrease in total length of hospital stay as well as a lowering in medical emergency team calls [147] and mortality rates [148]. More research will be needed to evaluate the impact of introducing continuous monitoring on general ward patients and the socio-technical factors involved, such as the alert burden on ward staff [149].

9. Conclusion – a call for action

The title of this review suggests that there was a time when vital signs were great. In truth we do not know if this was ever so. However, as older clinicians, we both feel that when we started our careers the vital signs and other bedside data were taken more seriously. The modern hospital culture has moved doctors and nurses away from the bedside and physical examination to the computerized nursing station and reliance on "high tech low touch" technology such as cardiac angiography, CT scans etc. We have presented a large amount of evidence that throughout the medical world vital signs are currently little valued, not regularly or accurately recorded, and frequently not acted on appropriately. Compared with other interventions in modern medicine the time and cost required to improve the quality of vital sign collection is trivial. Just as the availability of the pocket watch with a second hand made taking the pulse an essential medical task, so new technology such as smart phone apps and accessories should have revolutionize the medical industry's approach to taking, storing, interpreting and acting on vital signs. However, this has not happened. In many hospitals vital signs are still recorded on paper, which may not be legible. This paper record may still be kept at the end of the bed and later, if not lost, stuffed somewhere into a paper chart before it is archived. It is usually impossible to determine who measured the vital signs, what signs were measured, when they were measured, where they were measured, why they were measured, and what happened next. Even if eventually entered into an electronic medical record the information stored is usually not attributable, original, and contemporaneous, and there are no mechanisms in place to verify its accuracy. Indeed it is probable that few hospitals would keep their accreditation with regulatory bodies if they collected and acted on their laboratory results in the same way that they collect and act on vital signs. Sadly the situation is unlikely to change as long as hospital managers know that neither they nor their hospital will ever suffer any reputational or financial damage no matter how poorly vital signs are taken, recorded or responded to. Something needs to be done. Professional societies and regulatory bodies need to address this problem the same way they have with patient restraints, wrong site surgery's, catheter related infections and sepsis. If this kind of effort were applied to acquiring and recording vital signs accurately and acting on abnormalities promptly and appropriately hospital care would be safer, better and cheaper.

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