Identifying Patient Deterioration in the Emergency Department using Data Fusion Systems

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The Problem

UK NHS hospitals are required to use "track and trigger" (T&T) systems in which vital-sign observations are collected periodically from patients and scored. If the scores exceed a pre-defined threshold, care of the patient is escalated. T&T systems are typically used in wards where observations are relatively infrequent (4-8 hours).

In the Emergency Department (ED), observations are taken more frequently (<1 hour), and there is additional pressure to diagnose and treat patients within a 4-hour limit, as per national guidance.

The additional workload results in low levels of correctly completed T&T scores. Furthermore, the busyness of a typical ED means that it is likely that deterioration may be missed between observations.

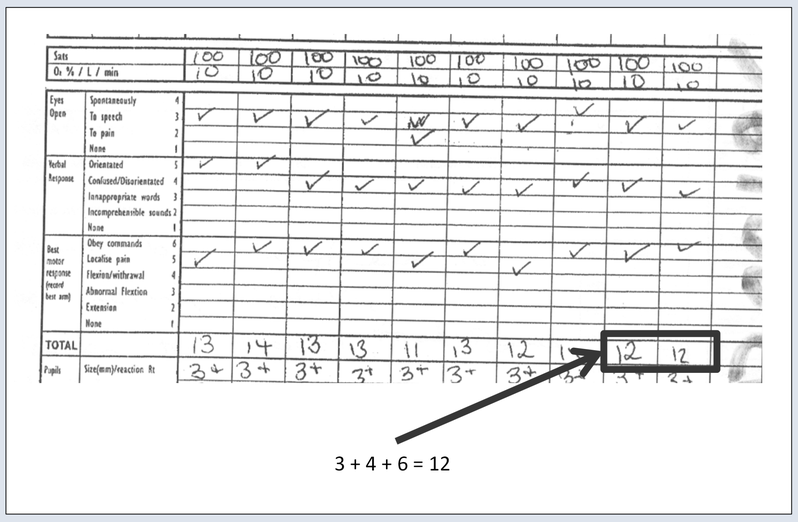


Figure 1: *An example of addition errors on a T&T chart. The total GCS score should add up to 13, but is incorrectly scored as 12. Addition errors were found to be uncommon, and the largest source of error was from T&T scores that had been incorrectly assigned.*

Quantifying the Problem

A retrospective study of 472 patients entering the Majors, Resus, and Observation room areas was conducted at the John Radcliffe (JR) Hospital, Oxford. Observation charts containing vital signs and T&T scores were collected.

It was found that only 65.7% of the 3025 observations collected had been scored using T&T, of which 20.3% were scored incorrectly (e.g. Figure 1). Furthermore, when T&T was incorrect, it was typically underscored. Potentially leading to missed escalations of care.

The results in this study were consistent with similar studies (see Armstrong et al.,2008; Prytherch et al., 2006)

Intervention

To determine if the percentage correctly completed T&T scores could be increased, and whether deterioration could be detected between observations, bed-side vital-sign monitors were connected to more unwell patients in the ED at JR hospital. Each monitor was linked to an intelligent data-fusion system, which generates alerts based on abnormal patient physiology.

During this phase of research, the data-fusion system was operated in "blinded" mode, so that alerts were alerts were not audible to staff, and recorded for retrospective analysis. In addition, paper observation charts were collected and transcribed to a database. Adult patients were selected at random for inclusion in the study, and consent was gained to use their data for analysis. The efficacy of the data fusion system and perfect (retrospective) T&T was assessed using "gold standard" labels of actual escalations for each patient, provided by a panel of ED clinicians who reviewed all the patient notes independently.

Figure 3: The output of the data fusion algorithm, as displayed on bedside tablet PCs

Outcome Measures:

Number of patients who had:

1. physiological escalations post-arrival correctly identified by T&T and data fusion (true positives)
2. Number of patients with no escalations, that had **no** alerts generated by T&T and data fusion (true negatives)

Continuous Data Fusion

The alarm rate from continuous vital sign monitors in acute wards is high, and contains many false alerts (e.g. Tsien and Fachler reported that 86% of ICU alerts were unwarranted). In addition, current vital sign monitors examine each vital sign independently, and are therefore insensitive to certain types of early patient deterioration where small deviations from normality in more than one vital sign may be a precursor to further deterioration.

The system introduced at the John Radcliffe Hospital ED deals with both of these issues by generating a Patient Status Index (PSI), which is a continuous variable that summarises the physiological condition of a patient. It is derived from the probability of a single set of observations with respect to a previously described cohort (Figure 2). An alert if the PSI exceeds 3.0 for 4 out of 5 consecutive minutes (for continuous variables). Because all vital sign variables are considered together, correlations between variables are implicitly captured.

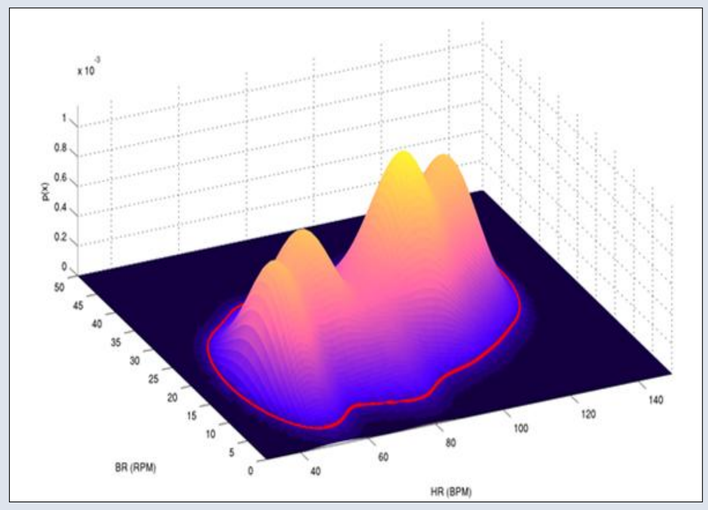


Figure 2: This figure demonstrates how the system generates a probability function for 2 vital sign parameters (HR and RR). The magenta line shows the alerting threshold. In the full system, the same procedure is used to generate a 5D model.

Results

The outcomes are shown in Figure 4. An event was "true positive" only if a PSI or T&T alert was generated within 15 minutes of the documented escalation. "True negatives" only occurred when no alerts were generated for the patients with no documented escalations. The combined system detected 39/51 in total, and 34/37 for which there was full continuous data. In comparison, manual T&T detects 14/51 escalations.

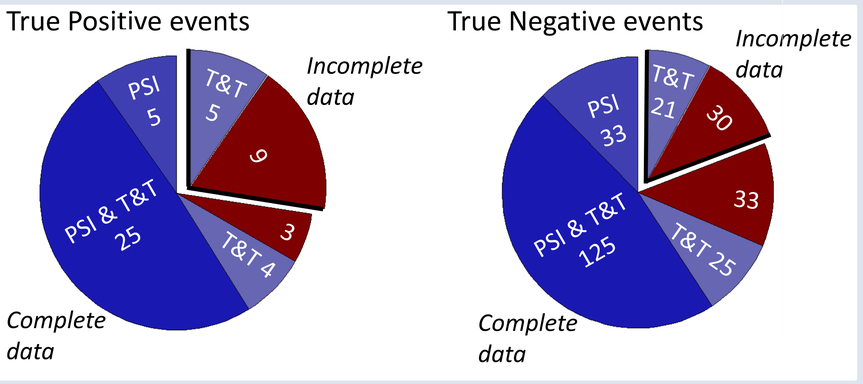
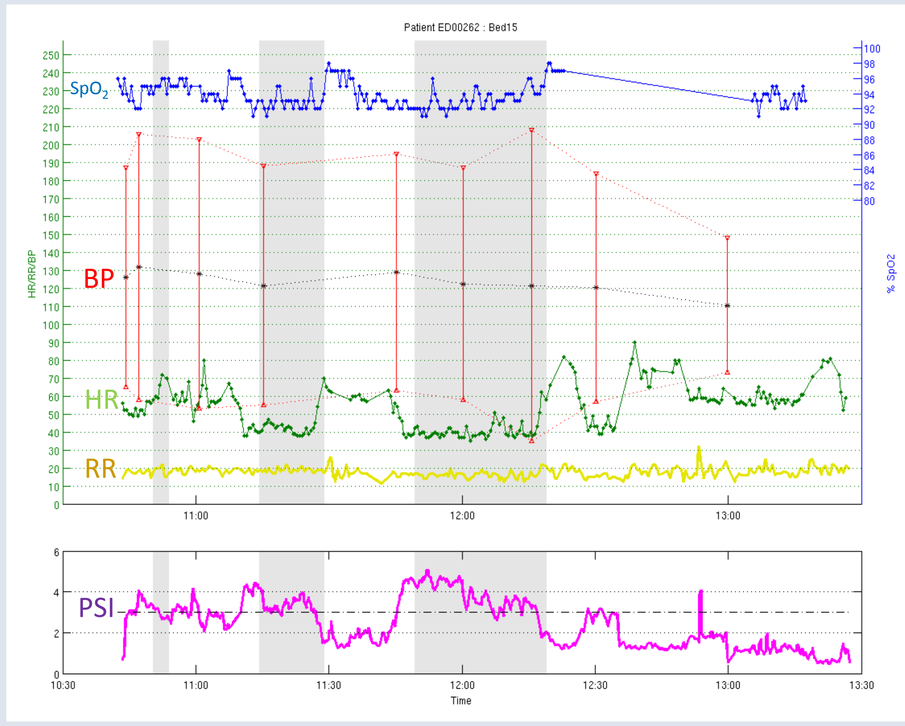


Figure 4: True positives and negatives for the T&T and data fusion system are shown in blue. Undetected escalations and instances where both systems generated false alerts are shown in red

Figure 5 shows an example patient who is likely to have benefitted from the combined system if alerts had been audible to staff.

Figure 5: Vital signs and Patient Status Index for study patient ED00262. In this example, manual observations were recorded at 11:00am, where the HR was ~60bpm. The continuous data shows bradycardia, which is reflected in the PSI. The patient was later reviewed at 16:00pm and diagnosed with symptomatic bradycardia



Future Work

The combination of automatic T&T score calculation and continuous data fusion is being used for active interventions in a 10,000 patient RCT-style study that will commence in Summer 2011 at the John Radcliffe Hospital, Oxford. During this period, nursing staff will be reminded when observations are due for each patient. Furthermore, they will be asked respond to alerts generated by the data fusion system by recording an additional observation. Our study will enable us to deduce whether computer-assisted T&T scoring alongside continuous monitoring can reduce short-term patient mortality and hospital length of stay.

Acknowledgements

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