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Clinical Actions as Indicators of Deterioration: Insights from Continuous Vital Sign Monitoring

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Abstract

Continuous vital sign monitoring on general hospital wards enables more frequent, earlier clinical interventions to avert patient deterioration. These interventions can affect clinical outcomes and may themselves serve as markers of impending decline. The present study examines the associations among these clinical actions, established clinical endpoints, and abnormal vital signs. This prospective cohort study included all patients receiving continuous vital sign monitoring on the gastrointestinal and oncological surgery ward and the internal medicine ward of a Dutch academic hospital between 1 August 2018 and 31 July 2019 (METC 2018-4330, NCT04189653). Clinical actions documented in the electronic medical records were evaluated for their correlations with patient outcomes, hospital length of stay, and duration of alarming monitoring periods.

In total, 1529 patients were enrolled, among whom 68 experienced a negative clinical endpoint. Overall, 2749 clinical actions were documented. These actions showed significant correlations with negative clinical endpoints ($\rho = 0.259$; $P < 0.001$; OR: 3.4-79.5) and with length of stay ($\rho = 0.560$; $P < 0.001$). Deviations in vital signs were also associated with clinical actions ($\rho = 0.025$–0.056; $P < 0.001$–$p = 0.018$). In the final 72 h before a clinical endpoint, the correlation between alarming minutes and clinical actions became markedly stronger ($\rho = 0.340$, $P < 0.001$). Specific clinical actions performed on general ward patients were associated with negative clinical outcomes, longer hospital stays, and episodes of abnormal vital signs—particularly in the period immediately preceding serious deterioration. Clinical actions, therefore, hold promise as an intermediate indicator of clinical decline.

Keywords: General ward, Continuous vital signs monitoring, Patient safety, Clinical deterioration, Predictive monitoring

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Introduction

Failure to detect clinical deterioration remains a serious concern on general hospital wards. It contributes to adverse outcomes, including increased morbidity, extended hospital admissions, ICU transfers, and mortality [1, 2]. Studies frequently employ clinical endpoints as both outcome measures and targets for early detection systems [3]. The adoption of continuous monitoring enables earlier recognition of potential deterioration, which, in turn, can prompt timely interventions that prevent negative endpoints [4-6]. Yet this situation presents a paradox: successful prediction of endpoints may be undermined by the very interventions triggered by those predictions. Consequently, forecasting the need for interventions could prove more clinically relevant than predicting endpoints that are ultimately avoided. In an ideal situation, this would create a self-regulating process in which responses

to abnormal vital signs restore stability and avert further decline.

Nevertheless, continuous monitoring often generates a large volume of alarms whose true clinical importance remains incompletely understood. Prior work by our group demonstrated a 7-fold rise in false alarms under continuous monitoring compared with intermittent checks, while other investigations have reported even greater increases [1, 7]. Patients who ultimately suffered negative clinical endpoints (RRT activation, ICU transfer, emergency surgery, or death) exhibited a higher total of alarming vital sign minutes across their hospital stay [7]. This suggests that periods of alarming vital signs may function as early warning signs of approaching deterioration. Among patients who did not reach negative endpoints, comparable accumulations of alarming minutes may have stimulated timely interventions that successfully prevented worsening. These individuals appear to have profited from continuous monitoring, consistent with earlier findings of reduced escalation events [5].

To address this paradox and better interpret the abundance of alarms produced by continuous monitoring, adopting clinical actions as a novel outcome measure may provide a useful approach. Long-range predictions of traditional endpoints are often of limited practical value to clinicians, who require immediate, actionable signals to intervene promptly. They depend on detectable patterns in continuous monitoring data to trigger early responses. Therefore, exploring links between clinical actions and conventional endpoints holds clear importance. Should strong associations exist, the ability to predict clinical actions would be particularly useful. Treating clinical actions as an intermediate step offers deeper insight into the deterioration process by highlighting actionable signals from monitoring data that align with interventions aimed at preventing poor outcomes [8-11]. The current study was designed to clarify the relationships between clinical actions and clinical deterioration. Specifically, we evaluated two hypotheses: (1) the frequency of clinical actions is associated with both negative clinical endpoints and overall admission length, and (2) clinical actions are linked to the volume of alarming minutes recorded during vital sign monitoring in the period leading up to clinical deterioration [8-10]. Through these analyses, we aim to assess the capacity of continuous vital sign monitoring to guide clinical actions and thereby help prevent deterioration.

Materials and Methods

This investigation took place on the gastrointestinal oncological surgery ward and the internal medicine ward at Radboud University Medical Center in the Netherlands. Every patient was routinely placed on continuous vital sign monitoring in accordance with standard hospital protocol. Real-time vital sign data remained available to the clinical team throughout the admission. The study population consisted of all patients admitted during a full one-year interval (August 2018 to July 2019) who had monitoring initiated within 12 h after arrival. Exclusion occurred if monitoring was halted due to patient refusal or because the patient could not tolerate the system, for instance, due to hyperactive delirium, skin contact allergies, or the initiation of a do-not-resuscitate policy. Only patients who had uninterrupted follow-up until reaching an endpoint were retained for the main analyses **(Figure 1)**.

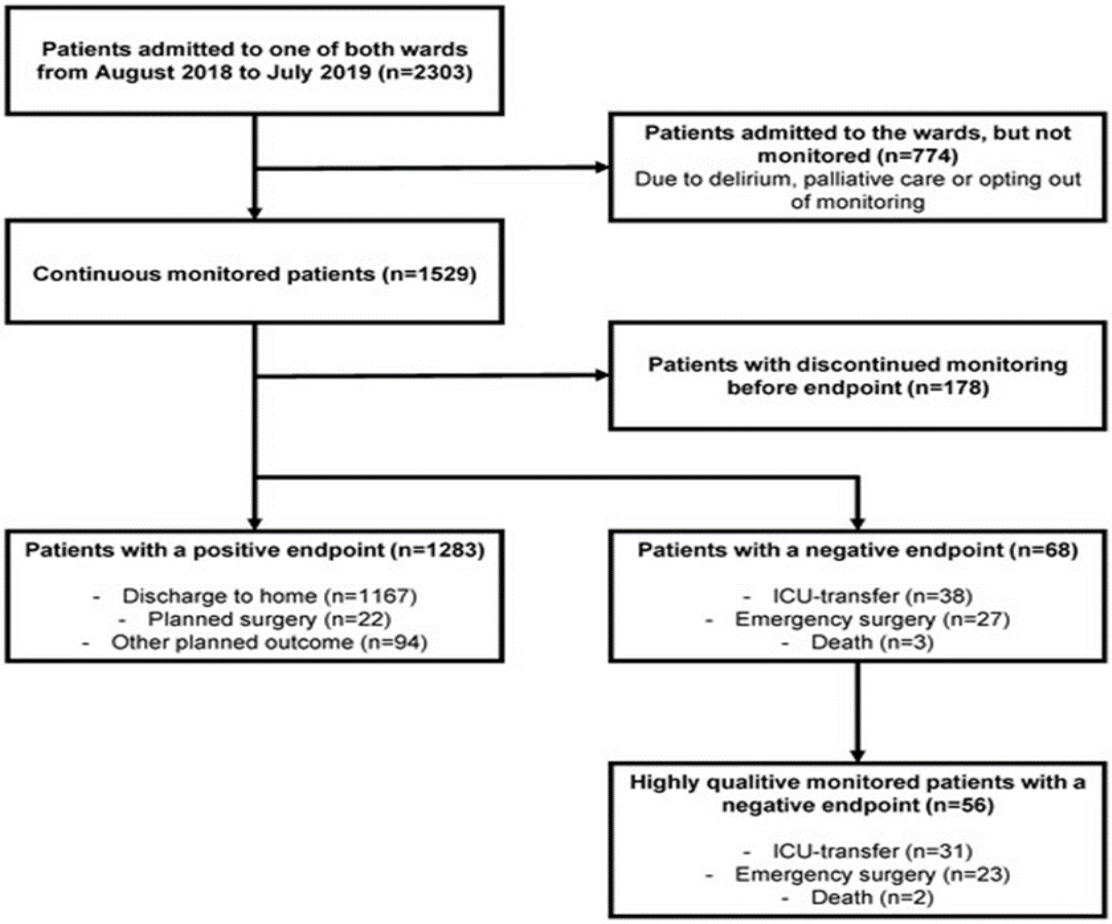

Figure 1. Population flow diagram.

The study complied fully with the Declaration of Helsinki and was approved by the local Medical Ethics Committee (METC 2018-4330). It was prospectively registered on ClinicalTrials.gov under identifier NCT04189653. Written informed consent was not required, as monitoring was part of routine care; patients could decline participation by opting out or were already recorded in the study database. Reporting followed the STROBE statement and checklist (https://www.equator-network.org/reporting-guidelines/strobe/, accessed on 21 August 2024).

Clinical data

The clinical status of each enrolled patient was daily evaluated. This was achieved by examining the complete electronic medical records (EMRs) daily, including every recorded intervention and entry, as well as all physician and nursing documentation. These reviews were conducted within 24 h of the events to reduce the risk of outcome-driven selection bias and to record information in the most forward-looking manner feasible. Every intervention, observation, and diagnosis was systematically logged. Any deviation in management that suggested clinical deterioration was timestamped to the nearest minute, based on the most verifiable and repeatable reference point available, such as the exact moment a medication was scanned for administration confirmation. For each distinct intervention, diagnostic step, or additional action, a reliable, reproducible timestamp was defined and entered into the database. Endpoints were documented using identical timing rules. Newly appearing unexpected symptoms were noted and incorporated into the patient's active problem list. A physician (RP or YE) carried out this documentation process. If several interventions clustered around the same moment, each was registered individually. Clinical endpoints were grouped into the following categories: discharge, transfer to a different ward, transfer to intensive care, unplanned surgical procedure, or death. Follow-up was discontinued if monitoring was suspended for more than 24 h, and the exact time of discontinuation was recorded. All data were entered into purpose-built electronic case report forms within a validated research database (Castor EDC, Castor EDC BV, Amsterdam, The Netherlands).

Clinical actions as an outcome

Once data collection ended, all logged entries were scrutinized for errors, inconsistencies, and duplicate registrations. Each case was thoroughly re-examined and discussed among the team to establish consensus regarding which interventions, observations, and

diagnoses represented actions potentially linked to deterioration. Every included action had to be directly traceable to an explicit order documented in the EMR, thereby supporting reproducibility. Only actions that clearly diverged from routine care and showed a plausible causal connection to emerging or progressing deterioration—determined by expert clinical judgment—were retained. Furthermore, these actions needed to qualify as suitable intermediate outcome measures, i.e., steps specifically taken to avert new or additional decline. The definitive collection of clinical actions encompassed newly documented symptoms and diagnoses, unplanned medication changes, physical procedures, and requests for specialist consultations. Any occurrence of these predefined actions is designated a "clinical action" and serves as an intermediate indicator of clinical deterioration in the study.

Vital sign monitoring data and alarming minutes

Under routine care protocols, every patient was attached to the ViSi Mobile monitoring system (Sotera Wireless, San Diego, CA, USA). As a result, heart rate, breathing rate, oxygen saturation, and noninvasive cuffless blood pressure were continuously tracked. A complete set of these parameters was stored in the research database at one-minute intervals. Analyses were based on these minute-by-minute recordings, together with the corresponding risk score from the Visensia Safety Index (VSI). This index is an automatic scoring tool that evaluates the overall deviation of vital signs from normal values (OBS Medical, Oxford, UK). Although the VSI algorithm can factor in core temperature, the ViSi Mobile only captures skin temperature. Because skin temperature readings are easily influenced by surrounding conditions and are not consistently reliable, temperature was excluded from the evaluation. Alarming minutes were identified when the VSI score reached or exceeded 3, in line with the supplier's recommended and validated cutoff, and were tallied for each minute. Any gaps in vital sign values within a minute were recorded as missing. Outlier readings that could not be reasonably explained by physiological factors were identified, removed, and excluded from further processing.

Defining endpoints, periods, and analysis

The study evaluated how the total count of clinical actions accumulated over each patient's hospital stay related to standard clinical endpoint measures. We first examined whether greater numbers of clinical actions were associated with negative endpoints (ICU transfer, emergency surgery, or death) using Spearman's rank correlation coefficients. We then determined the relative risk of care escalation across groups defined by progressively larger counts of actions. For admissions without a negative endpoint, we assessed the relationship between the number of clinical actions and the overall duration of hospitalization. These associations were tested with Spearman's rank correlation coefficients and Mann–Whitney U tests, following significant results from Kruskal–Wallis tests, while adjusting for differences in admission length.

In the subsequent phase, we analyzed the connection between the timing of clinical actions and the patterns observed in continuous vital sign recordings. Monitoring data were segmented into standardized 8-hour blocks, chosen to correspond with typical nursing shift durations and the longest recommended interval between observations under the hospital's Early Warning Score system. Within each block, average values for the vital parameters were computed; the mean deviation from normal was quantified using the VSI; the count of alarming minutes (VSI greater than 3) was determined; and the number of clinical actions occurring in that window was recorded. Correlations between alarming minutes and clinical actions were then tested across the initial 120 hours of all admissions. This 120-hour timeframe was selected because it approximated the median length of stay for the entire study group. In addition, we specifically investigated associations between clinical actions and alarming minutes in the final 72 hours preceding a negative endpoint. This sub-analysis included only admissions with a negative outcome that maintained at least 50% data completeness during the last 72 hours **(Figure 1)**. Due to the smaller number of cases in this subset, the time blocks were extended to 12 hours to ensure adequate data volume per interval. The 72-hour window was chosen as a practical upper limit for clinically actionable predictions and one that remained reasonable relative to the average admission length in the cohort.

All statistical computations were carried out using IBM SPSS version 25 (SPSS, Inc., Chicago, IL, USA). Summary statistics are reported as mean ± standard deviation (SD) or median with interquartile range (IQR), selected based on data skewness, as evaluated by the Shapiro–Wilk test. For proportions, 95% confidence intervals were calculated using the standard error method. Spearman's rank correlation coefficients (Spearman's ρ) were applied as the nonparametric measure of association. Comparisons of medians and distributions for non-normal data were performed with Mann–Whitney U tests and Kruskal–Wallis tests. Statistical significance was defined as a P-value < 0.05. Correlation strength was categorized as weak for coefficients below 0.3, moderate for coefficients between 0.3 and 0.5, and strong for coefficients above 0.5.

Results and Discussion

Patient and data characteristics

Continuous monitoring was successfully applied to 1529 patients who qualified for the main analysis. Among them, 68 experienced a negative clinical outcome, defined as ICU transfer, emergency surgery, or death. This represents an incidence rate of 4.4%, which is in line with the 3-year average negative outcome rate of 4.2% observed across our general wards [2]. Of these 68 patients, 56 met the stricter criteria for detailed analysis of the final 72-hour period, with at least 50% of data captured during that time **(Figure 1)**. **Table 1** presents the demographic and clinical characteristics of the included patients. In total, 10,074,490 minutes of continuous vital sign data were collected across 8890 patient days. Within this dataset, 51,842 minutes qualified as alarming based on a visensia safety index (VSI) score of 3 or higher, accounting for 0.5% of all measured minutes. Out of 10,396 initially registered actions, 3175 fulfilled the study's predefined selection standards and were designated as clinical actions. In the group with complete follow-up, 2749 clinical actions were documented overall. This included 642 actions among patients who reached a negative outcome and 566 actions in the subgroup of negative-outcome patients who also had high-quality monitoring data in the final period.

Table 1. Patient characteristics.

Category	Total monitored population	Closely monitored patients with a negative clinical outcome
Number of patients	1529	56
Medical/Surgical admissions	1005/524	24/32
Age (years)	60.1 ± 25.1	63.0 ± 23.7
Male (%)	51.9%	66.1%
ASA classification (I / II / III / IV)	48 / 695 / 793 / 23	0 / 19 / 36 / 1
Full code status at admission	87.0%	85.7%
Outcomes		
Discharged or planned outcome	1283	–
Monitoring discontinued	178	–
ICU transfers	38	31
Unplanned surgeries	27	23
Deaths	3	2
Length of stay (IQR)	100.7 (53.0–176.0)	98.0 (65.8–165.1)

Step 1: correlation of clinical actions and outcomes

A statistically significant positive association was observed between the total count of clinical actions and the occurrence of negative endpoints across the full study population ($\rho = 0.259$; $P < 0.001$). **Table 2** highlights this pattern through markedly elevated Relative Risk values for negative clinical endpoints as the number of clinical actions increased. The Relative Risk ratios ranged from 2.9 when comparing patients with 6–10 actions to those with 1–5 actions, reaching a peak of 42.3 when comparing patients with more than 15 actions to those with 0 actions.

Table 2. Relative risk ratios for negative endpoints across groups with increasing numbers of clinical actions.

	1–5 actions (n = 496)	6–10 actions (n = 91)	11–15 actions (n = 34)	> 15 actions (n = 15)
0 actions (n = 715)	5.9 (2.7–12.8; P < 0.001)	17.3 (7.7–38.7; P < 0.001)	21.7 (8.9–53.1; P < 0.001)	42.3 (18.3–97.7; P < 0.001)
1–5 actions (n = 496)	-	2.9 (1.7–4.9; P = 0.001)	3.6 (1.9–7.0; P = 0.001)	7.1 (4.0–12.7 P < 0.001)
6–10 actions (n = 91)	-	-	1.3 (0.6–2.5; P = 0.524)	3.8 (1.3–4.5; P = 0.005)
11–15 actions (n = 34)	-	-	-	1.9 (0.9–4.0; P = 0.077)

In the subgroup of patients who avoided any negative clinical endpoint, a greater number of clinical actions was associated with notably longer hospital admissions (Spearman $\rho = 0.560$; $P < 0.001$). The rate of actions per hour also showed a moderate association with total length of stay (Spearman $\rho = 0.394$; $P < 0.001$). Comparisons across groups with progressively more actions revealed consistent and significant differences in admission duration **(Table 3)**.

Table 3. Correlation between clinical actions and length of stay of discharged patients, between groups with an increasing number of clinical actions.

Action group	Length of stay (Median [IQR], hours)	MWU comparison vs. the previous group	Actions per hour (Median [IQR])	MWU comparison vs. the previous group

0 actions (n = 707)	73.0 [43.0–89.9]	–	0	–
1–5 actions (n = 463)	144.0 [91.0–215.0]	U = 81,742.5; Z = −14.5; P < 0.001	0.014 [0.009–0.023]	P < 0.001
6–10 actions (n = 75)	215.0 [168.0–333.0]	U = 9444.0; Z = −6.3; P < 0.001	0.033 [0.022–0.043]	U = 5981.0; Z = −9.1; P < 0.001
11–15 actions (n = 28)	368.0 [220.0–608.5]	U = 588.5; Z = −3.4; P = 0.001	0.036 [0.021–0.059]	U = 992.0; Z = −0.4; P = 0.667
> 15 actions (n = 10)	494.5 [348.8–856.0]	U = 100; Z = −1.326; P = 0.194	0.044 [0.021–0.063]	U = 120.0; Z = −0.7; P = 0.524

Step 2: correlation of clinical actions and vital signs

During the initial 120 hours of admission for the entire monitored group, modest but statistically significant correlations appeared between the number of clinical actions and the 8-hour average values for heart rate, respiratory rate, and blood pressure, as detailed in **Table 4**. These relationships stayed weak even when the composite Visensia Safety Index (VSI) replaced the individual vital parameters as the measure of deviation. No significant link was detected between clinical actions and the total count of alarming VSI minutes.

Table 4. Correlations between clinical actions and vital signs in the first 120 h of admission of the overall monitored population.

Parameter	Spearman's Rho	P-value
Heart rate	0.056	p < 0.001 *
Respiratory rate	0.032	p < 0.001 *
Oxygen saturation	0.003	p = 0.718
Systolic blood pressure	0.021	p = 0.018 *
Mean arterial pressure	0.025	p = 0.005 *
Visensia Safety Index (VSI)		
Average VSI	0.029	p < 0.001 *
Duration of alarming VSI (minutes)	0.007	p = 0.327

* = significant correlation.

However, analysis restricted to the final 72 hours before a negative clinical endpoint revealed a moderate association between the number of clinical actions and the volume of alarming VSI minutes ($\rho = 0.340$, $P < 0.001$). The pattern showed a clear inflection in the last 12 hours, where clinical actions increased more rapidly than the proportion of alarming VSI minutes **(Figure 2)**.

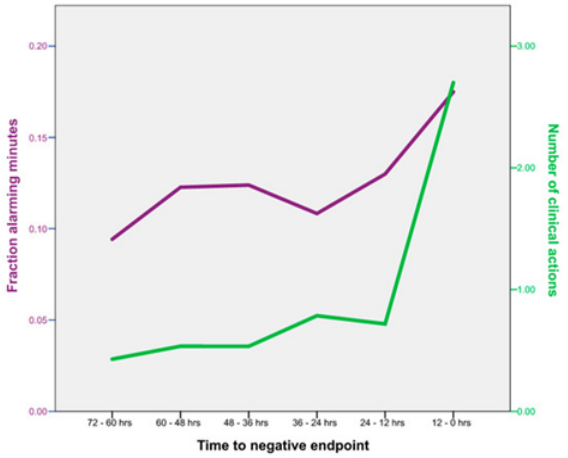

Figure 2. Graphical representation of the trend of alarming VSI minutes and the number of clinical actions.

This investigation evaluated the value of clinical actions recorded throughout hospital admission as an intermediate marker of impending clinical deterioration. It assessed how these actions relate to data from continuous vital sign monitoring. The findings supported both predefined hypotheses: (1) the volume of clinical actions was associated with negative clinical endpoints and longer hospital stays, and (2) clinical actions correlated with periods of increased alarming minutes under continuous monitoring in the lead-up to serious deterioration.

Previous reports from our team have shown that continuous monitoring can decrease the rate of negative clinical endpoints and identify early indicators of decline by increasing the number of alarming minutes among patients who later require escalated support [5, 7]. We hypothesized that these additional alarms would signal emerging problems and prompt staff to take timely clinical actions to prevent further decline. The present data confirm that individuals receiving more clinical actions carried a substantially elevated Relative Risk of experiencing a negative clinical endpoint. In addition, higher action frequency was associated with longer hospital stays, likely reflecting more complex and demanding clinical courses. For patients facing serious illness, isolated measures often fall short, requiring repeated and intensifying therapeutic steps. Successful interventions typically lead to stabilization of vital signs and overall improvement. Therefore, the sheer number of interventions needed to restore balance may serve as a useful gauge of the severity of deterioration, even when standard negative endpoints are avoided. Importantly, these associations reflect correlation rather than causation. Clinical actions constitute standard caregiver responses to observed vital sign abnormalities and other clinical signals, aimed at preventing further worsening.

Traditional endpoints tend to be binary (deterioration or no deterioration), whereas clinical actions supply a more

granular, stepwise measure. This enables finer evaluation of gradual physiological shifts and the impact of early interventions during the initial phases of decline. Continuous vital sign tracking, paired with advanced scoring tools, can detect subtle signs of instability long before overt deterioration. By treating clinical actions as intermediate outcomes, future studies can more precisely map how specific vital sign patterns and scores correspond to early dysregulation, paving the way for earlier and more targeted responses. This strategy supports the broader transition in healthcare from reactive, advanced deterioration to proactive, early intervention for initial signs of instability [4]. In this framework, each clinical action serves both as an indicator of illness severity and complexity and as practical evidence of the usefulness of continuous monitoring systems and their algorithms. Employing such intermediate measures should help researchers enhance predictive algorithms and scoring systems, improving sensitivity to early changes while limiting unwarranted alarms.

In patients who reached a negative endpoint, the number of alarming minutes correlated with the number of clinical actions. This finding supports the hypothesis that clinical actions represent intermediate stages of deterioration triggered by detectable deviations in vital signs. In contrast, no such correlation between alarming minutes and clinical actions was observed when the entire study population was examined. We suspect that vital sign deviations in the broader group often failed to surpass the relatively high alarm threshold set by the algorithm. Given that individual vital parameters showed only weak associations with clinical actions ($\rho = 0.025$-0.056), these links are currently too modest to support direct clinical application. Influences such as daily biological rhythms and physical activity levels probably exerted stronger effects on vital signs, thereby diluting the observed relationship with clinical actions. Although the present study did not adjust for these factors, previous investigations have demonstrated that continuous monitoring is highly sensitive to circadian variations and increased activity [12-15], which may also hold diagnostic value. Recent publications indicate that disruptions or the complete absence of normal circadian rhythm could serve as an early warning sign of clinical deterioration [12-17]. Multiple studies have documented a temporary suppression of circadian rhythm following surgery or during critical illness, followed by gradual restoration. Furthermore, van Ede reported that rising activity levels — often a marker of recovery — were accompanied by an increase in false alarms during periods of heightened movement [13]. Such temporary changes may even form part of a deliberate recovery strategy, since physiotherapy sessions commonly incorporate short-term fluctuations in vital signs as therapeutic targets [18].

This study investigated the simultaneous occurrence of vital sign deviations (measured as alarming minutes) and clinical actions, revealing several meaningful associations. Nevertheless, the same relationship could be approached from an alternative angle. Our analysis focused on deterioration, as indicated by abnormal vital signs, and the subsequent interventions aimed at correcting them. An inverted perspective would examine how clinical actions contribute to the normalization of vital signs. This viewpoint could help answer important questions regarding intervention effectiveness and whether specific actions successfully restored values to normal ranges. Differentiating between effective and ineffective responses to physiological imbalance might lead to a more precise definition of high-quality care. While this alternative perspective falls outside the scope of the current work, it offers a valuable direction for future investigations.

The relatively low rate of complications observed in our general ward population mirrors everyday clinical practice and provides a more realistic picture than cohorts reported in several other studies [1, 10, 12]. Our observed complication rate of 4.4% is similar to or slightly below the 5–8% range documented elsewhere [1, 19, 20]. In settings with low baseline event rates, the impact of confounding variables tends to become more noticeable. This pattern is consistent with well-known properties of diagnostic and screening tests. When the prevalence of the target condition is low, positive predictive value declines, and subtle relationships between predictors and outcomes are more readily obscured by background noise [21]. Even though clinical actions were used here as a more frequently observed intermediate outcome, the overall scarcity of adverse events still constrained the models' sensitivity. It contributed to the generally weaker correlations observed. However, a focused sub-analysis among patients who required care escalation uncovered stronger links between alarming minutes and clinical actions, highlighting the particular value of continuous monitoring in higher-risk subgroups with elevated event rates.

Continuous vital sign monitoring is gradually supplanting traditional intermittent checks as the preferred method for identifying clinical deterioration [1, 4, 8]. While rigid thresholds work reasonably well for occasional spot checks, different alerting strategies and adjusted thresholds may prove more effective when data are collected continuously [4, 12]. It is therefore essential to develop better methods for separating pathological changes in vital signs from those arising from non-pathological causes. Using clinical actions as an intermediate outcome provides a useful bridge between observed vital sign deviations and actual clinical deterioration. This framework can deepen our

understanding of how monitoring data translates into real-world interventions, ultimately supporting earlier identification of at-risk patients and more timely responses. Integrating additional variables, such as patient activity levels and circadian patterns, into future predictive models could further improve accuracy by filtering out normal physiological fluctuations. Such refinements would assist in care planning, more efficient resource allocation, and even safer decisions regarding early hospital discharge [22].

Recent advances in machine learning and artificial intelligence underscore the importance of clearly defining the gradients of clinical deterioration [3]. By introducing intermediate outcomes that precede conventional endpoints, the present study offers a practical framework for achieving earlier detection and intervention. This experimental broadening of the concept of clinical deterioration may lead to more refined predictive algorithms and, ultimately, better patient outcomes.

The main strength of this study is its inclusion of a real-world patient population with very limited selection criteria, which improves the applicability of the findings to everyday practice. Because continuous vital sign monitoring was implemented as routine standard care, clinical staff could respond directly to alarms as part of their normal workflow. Although the study was limited to a surgical ward and an internal medicine ward, the broad mix of patients who did and did not undergo surgery is considered representative of the typical hospital population. For future studies involving other specialty wards, the predefined clinical actions listed here would need to be expanded to include relevant specialty-specific interventions. Nonetheless, we consider that the majority of clinical deteriorations share common underlying causes and follow similar pathways across different specialties, such as infections, shock, ischemia, and metabolic disturbances.

Despite meticulous documentation, occasional minor mismatches may have arisen between the recorded time and the actual moment of certain clinical actions. However, such discrepancies are unlikely to have meaningfully altered the overall results. The study was unable to adjust or account for confounding influences on vital sign parameters, including circadian rhythm. This limitation may have reduced our ability to pinpoint patients who could have benefited from timely intervention to avert deterioration.

Because the research was embedded in routine clinical practice, the completeness and quality of the monitoring data were influenced not only by daily workflow demands but also by technical issues with the devices, logistical constraints, established working protocols (for example, hygiene and infection control measures), and various external factors. As a result, a relatively small number of patients had to be excluded from the deeper analysis due to insufficient data capture.

Conclusion

This study, conducted in two general wards (one surgical and one internal medicine), indicates that clinical actions can serve as a useful intermediate outcome measure. It demonstrates associations between the frequency of clinical actions, the occurrence of negative clinical endpoints, and hospital length of stay. In addition, among patients who suffered severe clinical deterioration, the number of alarming minutes was linked to the timing of concurrent clinical actions. Additional research is required to further evaluate the capacity of continuous vital sign monitoring and associated scoring systems to guide appropriate and timely clinical interventions, assess the effectiveness of those interventions, and ultimately help prevent clinical deterioration.

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Conflict of interest: None

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Ethics statement: This study was conducted in accordance with the Declaration of Helsinki on Medical Research and was approved by the Medical Ethics Committee (METC 2018-4330, approved on 30 April 2018).

Patient consent was waived since continuous vital sign monitoring was the standard of care at these wards. Our academic hospital notifies every patient that their data can be used anonymously for research, but also offers an opt-out option. If this is chosen, these patients are not included in our research.

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