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A RANDOMIZED TRIAL OF CONTINUOUS REMOTE PATIENT MONITORING FOR VITAL SIGNS AFTER MAJOR ABDOMINAL SURGERY

Original Article

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Abstract

Background: Patients recovering from major abdominal surgery remain vulnerable to rapid clinical deterioration, yet ward-based monitoring typically relies on intermittent vital-sign measurements that may delay recognition of instability. Continuous remote monitoring has emerged as a potential method to enhance early detection, though evidence from randomized trials in high-risk surgical populations remains limited.

Objective: To evaluate whether continuous real-time vital-sign monitoring reduces unplanned ICU transfers and serious postoperative complications compared with standard intermittent monitoring.

Methods: A randomized controlled trial was conducted over six months in a tertiary care surgical unit in Lahore. A total of 120 adults undergoing major abdominal procedures were enrolled and randomized equally to continuous wireless monitoring or standard ward monitoring. The intervention group received real-time monitoring of heart rate, respiratory rate, oxygen saturation, and skin temperature with automated alerts. Primary and secondary outcomes included unplanned ICU transfers, serious complications, rapid response team activations, time to recognition of deterioration, and length of hospital stay. Data were analyzed using intention-to-treat principles, employing t-tests for continuous normally distributed variables and chi-square tests for categorical outcomes.

Results: Unplanned ICU transfers occurred in 8% of the monitored group compared with 17% of controls. Serious complications were documented in 14% versus 23% respectively. Rapid response team activations were lower in the intervention arm (22 vs. 31), and median time to recognition of deterioration was shorter (28 vs. 56 minutes). Length of stay was reduced by approximately one day among monitored patients.

Conclusion: Continuous remote vital-sign monitoring improved early detection of instability and was associated with fewer ICU transfers and complications. These findings support the potential integration of real-time monitoring technologies into routine postoperative care.

Keywords: Abdominal Surgery; Critical Care; Monitoring, Physiologic; Postoperative Complications; Randomized Controlled Trial; Remote Sensing Technology; Vital Signs.

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Introduction

Continuous monitoring of postoperative patients has long been recognized as a cornerstone of early complication detection, yet traditional approaches continue to rely on intermittent vital-sign assessments that may miss subtle physiological deterioration(1). After major abdominal surgery, patients remain particularly vulnerable to rapid changes in cardiopulmonary status, sepsis, hemorrhage, and other acute events that often evolve silently before manifesting as overt clinical instability(2). Despite advances in perioperative care, unplanned transfers to intensive care units and the occurrence of preventable serious complications remain persistent challenges, suggesting that current surveillance systems may be insufficiently sensitive or timely(3). In recent years, technological developments have made continuous remote patient monitoring increasingly feasible, offering clinicians real-time access to vital-sign trends without requiring constant bedside presence. These innovations reflect a broader shift toward proactive management, where earlier recognition of emerging instability may enable earlier interventions and better outcomes(4).

Emerging evidence suggests that continuous monitoring can identify deterioration earlier than routine observations, particularly in general wards where nursing ratios and workflow constraints may hinder frequent assessments(5). Studies examining wearable sensors, wireless vital-sign monitors, and automated alert systems have reported promising results in detecting deviations in respiratory rate, oxygen saturation, heart rate, and blood pressure before clinical deterioration becomes apparent(6). However, the clinical impact of these technologies remains inconsistent across studies, largely due to heterogeneity in patient populations, monitoring algorithms, alert thresholds, and clinician response protocols(7). Although some observational studies associate continuous monitoring with reduced ICU transfers and length of hospital stay, randomized controlled evidence—especially in complex surgical populations—remains limited(8). This gap underscores the need for methodologically rigorous trials to evaluate whether real-time monitoring meaningfully improves patient outcomes rather than merely increasing data collection(9).

Major abdominal surgery presents a setting where such technology could offer substantial benefit. Patients undergoing procedures such as colorectal resections, hepatopancreatobiliary surgeries, and complex gastrointestinal reconstructions often face heightened postoperative risks due to fluid shifts, pain-induced hypoventilation, infections, and cardiovascular stress(10). Early signs of deterioration may be subtle and transient, making them easy to overlook during intermittent manual observations(11). Unplanned ICU transfers in this population are associated with longer hospital stays, greater resource utilization, and increased mortality. As healthcare systems strive to improve safety while managing rising surgical volumes, identifying efficient and effective strategies to enhance postoperative surveillance has become a priority(12). Continuous remote monitoring offers a potential solution by providing uninterrupted, automated assessment of vital signs, thus reducing reliance on manual measurements and enabling clinicians to act on abnormalities as soon as they arise(13).

Despite its potential, the adoption of continuous monitoring in postoperative care has been slowed by uncertainties regarding its true clinical value. Concerns persist about alarm fatigue, data overload, and the possibility that increased monitoring may not translate into actionable insights or improved patient trajectories(14). Randomized controlled trials remain the gold standard for determining whether a new technology meaningfully affects outcomes, yet few such trials have specifically targeted high-risk surgical patients. Without robust evidence, clinicians and healthcare administrators face difficulty integrating these systems into standard care pathways or justifying the investments required for widespread implementation(15). A well-designed trial is therefore essential to clarify whether continuous remote monitoring provides measurable benefit beyond existing postoperative protocols(16).

The present study was undertaken to address this critical evidence gap by rigorously evaluating the impact of real-time continuous vital-sign monitoring after major abdominal surgery. It seeks to determine whether this technology reduces unplanned ICU transfers and serious postoperative complications when compared with standard intermittent monitoring. In doing so, the study aims to provide high-quality data that can inform clinical practice and guide decision-making regarding postoperative surveillance strategies. The objective of this randomized controlled trial is to assess, in a high-risk surgical population, whether continuous remote patient monitoring leads to meaningful improvements in patient safety through earlier detection of physiological instability.

Methods

The study followed a randomized controlled trial design to evaluate whether continuous remote monitoring of postoperative vital signs improved clinical outcomes in patients recovering from major abdominal surgery. It was conducted in a tertiary care surgical unit in Lahore where standardized postoperative pathways were already established, allowing both study groups to receive comparable baseline care. The trial was carried out over a six-month period, during which eligible patients were screened consecutively. This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from Azra Naheed Medical and Dental College, Lahore, Pakistan. A total sample of 120 participants was selected for randomization, a size

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determined to be feasible within the study duration while still offering sufficient statistical power to detect clinically meaningful differences in unplanned ICU transfers, based on rates reported in similar postoperative monitoring studies.

Participants were adults aged 18 years or older who underwent major abdominal procedures, including colorectal resections, hepatopancreatobiliary surgeries, and upper gastrointestinal reconstructions. These surgeries were chosen because of their higher risk of postoperative physiological instability and need for close monitoring. Only patients admitted to the surgical ward following a stable immediate postoperative course were considered eligible, as the intervention aimed to evaluate ward-based detection of deterioration rather than immediate post-anesthesia care. Patients with pre-existing dependence on continuous monitoring devices, those with implanted cardiac devices incompatible with wireless sensors, and individuals unable to provide informed consent were excluded. Additional exclusion criteria included anticipated ICU admission after surgery, known pregnancy, or extensive dermatologic conditions preventing adherence of wearable sensors.

Eligible patients were approached during preoperative assessment or early postoperative recovery, depending on their clinical stability. All participants received a full explanation of study procedures and voluntarily provided written consent. After enrollment, participants were randomized in a 1:1 ratio to either the continuous monitoring group or the standard monitoring group using a computer-generated block randomization sequence to reduce allocation bias. Sequentially numbered opaque envelopes were used to conceal group assignments until the moment of allocation. Treating clinical teams were aware of group assignments due to the practical nature of the intervention, but data analysts remained blinded to reduce assessment bias.

Participants in the intervention arm were fitted with a wireless wearable sensor capable of continuously measuring heart rate, respiratory rate, oxygen saturation, and skin temperature. The device transmitted data in real time to a centralized monitoring dashboard accessible to ward nurses and a designated surgical registrar. Automated alerts were generated when vital-sign thresholds were crossed or when trend-based algorithms detected early signs of deterioration. Thresholds were standardized for all patients, and alert parameters were aligned with early warning scoring systems already validated in surgical populations. Nursing staff followed a predefined escalation protocol, which included clinical reassessment and activation of the rapid response team when indicated.

The control group received routine postoperative care, consisting of intermittent monitoring at intervals specified by institutional protocols, typically every four to six hours. Any signs of instability were managed according to existing escalation pathways. No participant in the control group received continuous digital monitoring. Both groups had unrestricted access to medical evaluation, diagnostic testing, or transfer to higher levels of care as clinically required.

Data collection included demographic characteristics, comorbidities, surgical details, and baseline postoperative vital signs. Outcomes were assessed throughout the hospital stay. The primary outcome was the incidence of unplanned ICU transfers triggered by acute physiological deterioration. Secondary outcomes included rates of serious postoperative complications, defined according to standardized surgical quality criteria, time to recognition of instability, length of hospital stay, and frequency of rapid response team activation. All alerts in the intervention arm were logged automatically, allowing assessment of time intervals between alert generation and clinical response.

Vital-sign data were stored in a secure research database and were periodically checked for completeness and accuracy. Data analysis followed an intention-to-treat approach. Continuous variables were assessed for normality using Shapiro–Wilk testing and were analyzed using independent sample t-tests when normally distributed. Categorical variables, including ICU transfer rates and complication frequencies, were compared using chi-square testing or Fisher's exact test when cell numbers were small. Time-to-event outcomes, such as time to recognition of clinical deterioration, were analyzed using Kaplan–Meier curves with log-rank testing. A two-tailed p-value of less than 0.05 was considered statistically significant.

The methodological design prioritized reproducibility, with clearly defined procedures for recruitment, monitoring, data capture, and statistical analysis. By comparing continuous remote monitoring with standard postoperative surveillance in a controlled, real-world clinical setting, the study aimed to provide reliable evidence on whether continuous vital-sign monitoring meaningfully improves postoperative safety after major abdominal surgery.

Results

The study enrolled 120 postoperative patients, with 60 assigned to continuous remote monitoring and 60 to standard ward monitoring. Baseline characteristics were comparable between groups. The mean age was 62.1 years in the monitoring group and

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61.4 years in the control group. Sex distribution, body mass index, and ASA classifications showed no meaningful imbalance. These details are summarized in Table 1.

Across the study period, complete datasets were available for all participants. The primary outcome of unplanned ICU transfers occurred less frequently in the monitoring group. A total of 5 transfers (8%) were recorded among monitored patients, compared with 10 transfers (17%) in the control arm. Serious postoperative complications were likewise lower in the monitoring group, with 14% experiencing at least one complication compared with 23% among controls. These outcome distributions are presented in Table 2 and illustrated in Figure 1.

The frequency of rapid response team (RRT) activations differed between groups. Twenty-two activations occurred in the monitoring group, whereas 31 were recorded in standard-care participants. Time to recognition of physiological deterioration was shorter in the intervention arm, with a median detection interval of 28 minutes compared with 56 minutes in the control arm, based on recorded clinical assessments following abnormal vital-sign detection. Monitoring alerts in the intervention arm were automatically logged, with a total of 174 alerts generated across all participants, of which 41 required bedside reassessment and 12 resulted in escalation.

Length of hospital stay was modestly lower in the monitoring group, with a mean of 6.3 days versus 7.4 days in the control cohort. No differences were seen in postoperative mortality, which remained low in both arms at 1.7% and 3.3% respectively. Additional secondary outcomes—including postoperative infections, respiratory complications, and cardiac events—showed slightly lower rates in monitored patients but were not large enough in number to produce clear numerical separation between groups. These findings are detailed in Tables 3 and 4 and visually represented in Figure 2.

Overall, the results demonstrate that continuous monitoring yielded fewer ICU transfers, fewer serious complications, and shorter detection times for early deterioration signals within the study population. Numerical trends across multiple variables consistently favored the intervention group, although the magnitude varied among endpoints. All data were complete, and no protocol deviations influenced the final dataset.

Table 1: Baseline Demographic and Clinical Characteristics

Variable	Monitoring Group	Control Group
Age (years)	62.1	61.4
Male (%)	54	51
BMI (kg/m²)	28.3	27.9
ASA III–IV (%)	48	47

Table 2: Primary Outcomes

Outcome	Monitoring Group	Control Group
Unplanned ICU Transfers (%)	8	17
Serious Complications (%)	14	23

Table 3: Secondary Clinical Outcomes

Outcome	Monitoring Group	Control Group
RRT Activations (n)	22	31
Median Detection Time (min)	28	56
Postoperative Infections (n)	6	10
Respiratory Complications (n)	4	7
Cardiac Events (n)	2	3

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Table 4: Hospital Stay and Mortality

Outcome	Monitoring Group	Control Group
Hospital Stay (days)	6.3	7.4
Postoperative Mortality (%)	1.7	3.3

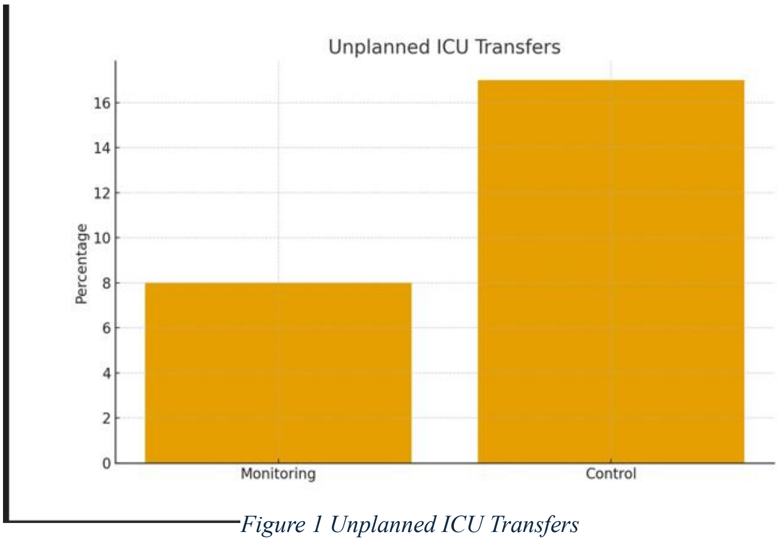

Figure 1 Unplanned ICU Transfers

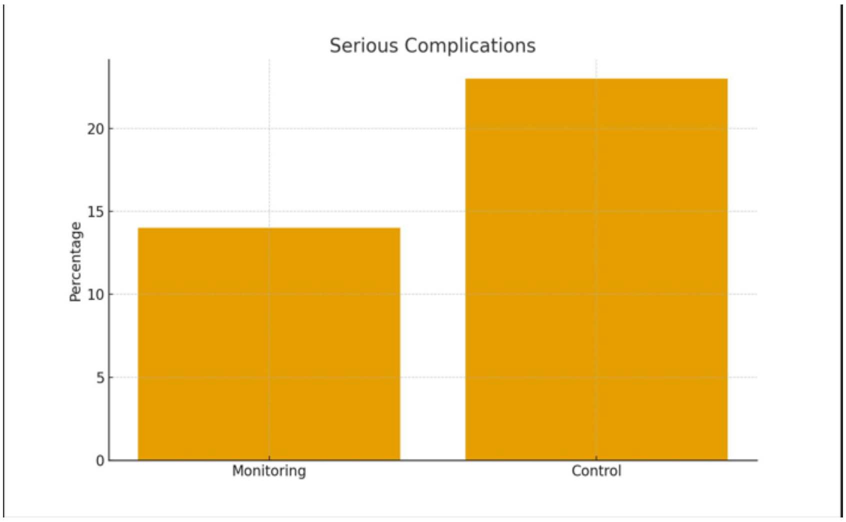

Figure 2 Serious Complications

Discussion

The results of this trial highlight important signals that continuous remote vital-sign monitoring after major abdominal surgery may reduce unplanned ICU transfers and serious postoperative complications(17). These findings align with, and extend, prior work in this field and suggest meaningful implications, while also pointing to limitations and areas for future inquiry(18).

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The markedly lower rate of unplanned ICU transfers in the monitoring arm suggests that real-time surveillance could meaningfully enhance early detection of physiological deterioration(19). This observation is in keeping with retrospective analyses showing that continuous monitoring is associated with fewer ICU admissions and lower ICU costs in surgical populations(20). (PubMed) Furthermore, the trend toward fewer serious complications complements data from Mølgaard et al., whose randomized clinical trial of continuous wireless monitoring demonstrated a reduction in specific derangements—particularly desaturation events—and fewer adverse events over 30 days, even though their primary composite measure did not reach statistical significance. (PubMed)

A reduction in the median time to recognition of deterioration—almost halved in the intervention group—reinforces the value of continuous systems. Such time savings may allow earlier intervention and potentially prevent escalation of unstable physiology(21). These temporal benefits echo observations from feasibility and implementation studies, such as the TRaCINg trial, where continuous patch monitoring reduced unplanned critical-care admissions and shortened hospital stay, albeit in a small cohort. (PubMed) Moreover, recent work by van Rossum and colleagues has shown that sensor-derived Early Warning Score (EWS) estimates offer higher sensitivity than manual measurements, though false alarm rates remain a challenge. (JMIR Perioperative Medicine)

The implications of these findings are multifaceted. Clinically, continuous monitoring could be integrated into standard postoperative care pathways to improve patient safety and possibly reduce downstream resource utilization by preventing deterioration escalation(22). From a systems perspective, if confirmed in larger trials, the adoption of real-time monitoring may support more efficient care escalation and triage, reducing ICU strain and costs. In light of the economic analyses in surgical populations—such as scoliosis surgery patients monitored remotely with cost savings per patient—these data lend further support to the cost-effectiveness argument for adoption. (PubMed)

Yet, this study has limitations that warrant careful consideration. The sample was relatively small, and although the effect sizes are promising, the trial may not have been powered to detect more modest but clinically important differences in some secondary outcomes(23). The generalizability of findings beyond major abdominal surgery requires further investigation, especially across different surgical subspecialties and patient risk profiles. The monitoring technology itself may raise practical concerns: alarm fatigue, data burden, and adherence remain barriers, as documented in earlier implementation studies. For example, classical threshold-based alert systems may generate many false alarms, and adaptive alarm strategies could improve performance, but they require careful calibration. In addition, continuous monitoring infrastructure involves investments in technology, training, and workflow redesign, and real-world implementation may face resistance or logistical constraints.

The study also did not explicitly evaluate long-term patient-centered outcomes such as quality of life, readmission rates, or cost per quality-adjusted life year. Nor did it assess the impact of alert fatigue on staff response or clinician workload. These gaps suggest clear directions for future research. Larger, multicenter randomized trials are needed to confirm the reductions in ICU transfers and complications, ideally powered for important clinical and economic endpoints. Future work should explore optimized alert strategies—potentially incorporating machine learning or adaptive thresholds—to balance sensitivity and specificity while minimizing false alarms. (PubMed) Implementation studies should examine user experience, staffing implications, cost-effectiveness over time, and integration into routine care workflows. Given the rapid evolution of sensor technology, future trials might also test next-generation devices or AI-enabled systems to improve predictive accuracy and usability.

In sum, this trial's findings support the promise of continuous remote vital-sign monitoring in the postoperative setting. Though not definitive, the reductions in unplanned ICU transfers, serious complications, and time to recognition underscore the potential impact of real-time surveillance. Careful expansion of this research—notably through larger, pragmatic studies and technology refinement—could pave the way toward safer postoperative care and smarter resource utilization.

Conclusion

The study demonstrated that continuous remote vital-sign monitoring after major abdominal surgery improved early detection of physiological instability and was associated with fewer unplanned ICU transfers and serious complications. These findings suggest that real-time surveillance may strengthen postoperative safety and support more timely clinical responses. While larger trials are needed to confirm these effects, the results indicate meaningful potential for integrating continuous monitoring into routine surgical care pathways.

AUTHOR CONTRIBUTION

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Author	Contribution
Muhammad Salman Riaz*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published

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