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Original Article

A Cluster-Controlled Trial of a Lean Management System Redesign on Emergency Department Throughput and Clinician Burnout

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ABSTRACT

Background: Emergency departments frequently face operational inefficiencies such as overcrowding, prolonged patient waiting times, and workflow fragmentation. These pressures not only affect patient throughput but also contribute to psychological strain and burnout among clinicians. Lean management, a process improvement framework focused on eliminating waste and optimizing workflow, has increasingly been adopted in healthcare settings to address these challenges. However, evidence evaluating its simultaneous impact on operational efficiency and clinician well-being remains limited, particularly in real-world emergency department environments. Objective: To evaluate the effect of a Lean management system redesign on emergency department throughput indicators and clinician burnout levels. Methods: A randomized controlled trial with department-level allocation was conducted over four months in emergency departments within the Islamabad–Rawalpindi healthcare region. Departments were randomly assigned to either a Lean management intervention or standard operational practice. A total of 72 clinicians, including physicians, nurses, and clinical officers, participated in the study. Operational efficiency outcomes included waiting time to physician assessment, total emergency department length of stay, and rate of patients leaving without being seen. Clinician burnout was assessed using the Maslach Burnout Inventory–Human Services Survey. Data were collected at baseline and post-intervention, and statistical analyses were performed using independent and paired t-tests, analysis of variance, and Pearson correlation analysis. Results: Emergency departments implementing Lean-based workflow redesign demonstrated significant improvements in operational performance. Mean waiting time to physician assessment decreased from 41.6 ± 9.3 minutes to 28.7 ± 7.4 minutes, while average department length of stay declined from 196.4 ± 34.5 minutes to 158.2 ± 30.6 minutes. The proportion of patients leaving without being seen also decreased. Clinicians in intervention groups reported lower emotional exhaustion scores (22.6 ± 6.3) compared with those in control groups (26.4 ± 6.5). Shorter patient waiting times were moderately associated with reduced burnout levels. Conclusion: Lean management system redesign improved both operational efficiency and clinician well-being within emergency department settings, suggesting that structured workflow optimization may contribute to more sustainable and supportive healthcare environments. Keywords: Burnout, Emergency Service Hospital, Health Care Quality Improvement, Lean Management, Patient Flow, Professional Burnout, Workflow.

INTRODUCTION

Emergency departments serve as the front line of modern healthcare systems, providing rapid assessment and treatment for patients with conditions ranging from minor injuries to life-threatening emergencies (1). Over the past two decades, rising patient volumes, increasing clinical complexity, and limited healthcare resources have placed extraordinary pressure on emergency care systems worldwide (2). Additionally, emergency department overcrowding is a critical factor that compromises patient safety and increases staff load, creating prolonged waiting times (3). These pressures frequently manifest as overcrowded waiting areas, prolonged patient length of stay, delayed diagnostics, and extended boarding times for admitted patients. Such inefficiencies not only compromise operational performance

but also have meaningful implications for patient safety, quality of care, and public trust in healthcare institutions (4). Recognition of emergency as a specialty can improve the approaches, and improving clinician wellbeing is a necessary goal for the healthcare system, providing emergency physicians with control of their profession (5). As emergency departments struggle to balance timely service delivery with safe clinical decision-making, health system leaders have increasingly recognized the need for systematic approaches that improve both workflow efficiency and the working conditions of healthcare professionals (6).

In the face of increasing pressures such as limited resources increasing patients volumes and rising expectations of stakeholders, effective hospital management depends on efficient operations (7). Operational inefficiencies in emergency departments are rarely the result of a single bottleneck (8). Instead, they arise from complex interactions among patient demand, staffing levels, physical infrastructure, diagnostic turnaround times, and communication processes across clinical teams. Traditional attempts to improve performance have often focused on isolated interventions, such as increasing staffing or expanding physical capacity. While such measures may produce temporary relief, they rarely address the underlying structural inefficiencies embedded within care delivery processes (9). Consequently, attention has shifted toward management frameworks capable of redesigning systems of work rather than merely adding resources. Among these approaches, Lean management has gained increasing prominence in healthcare as a strategy for eliminating waste, streamlining workflow, and enhancing value from the perspective of both patients and providers.

Lean management, originally developed within manufacturing industries, emphasizes continuous improvement, standardization of processes, and frontline staff engagement in problem-solving (10). When applied to healthcare environments, Lean principles aim to reduce non-value-adding activities, improve coordination across clinical teams, and ensure that patient care flows smoothly through the system. Several healthcare organizations have implemented Lean initiatives within emergency departments to address delays in triage, diagnostic testing, and patient disposition. Early reports suggest that such initiatives can improve operational metrics such as patient throughput, waiting time, and overall length of stay (11). However, many of these studies have relied on observational designs or single-site quality improvement projects, limiting the strength of causal inference and the generalizability of findings across diverse healthcare settings.

Beyond operational performance, the human consequences of emergency department work environments have become an increasingly urgent concern (12). Clinicians working in emergency settings frequently experience high levels of psychological stress due to unpredictable patient volumes, time pressure, emotionally demanding encounters, and exposure to critical illness and trauma (13). Prolonged exposure to such conditions contributes to burnout, a syndrome characterized by emotional exhaustion, depersonalization, and reduced professional efficacy. Burnout among emergency physicians and nurses has been associated with decreased job satisfaction, increased turnover intentions, and potential adverse effects on patient care. Importantly, operational inefficiencies and chaotic work environments may exacerbate these psychological burdens by forcing clinicians to spend substantial time navigating fragmented processes rather than focusing on patient care (14).

While Lean management systems are designed to streamline workflow and reduce unnecessary workload, their influence on clinician well-being remains an area of active debate. The lean management transferring to dynamic environment such as health care poses many integration issues (7). Proponents argue that eliminating inefficiencies can reduce stress and cognitive burden by creating more predictable, organized clinical environments. Critics, however, caution that poorly implemented process redesign may inadvertently intensify work pace or introduce new performance pressures (15). As a result, evaluating Lean interventions solely on the basis of operational outcomes provides an incomplete understanding of their broader impact on healthcare systems. A comprehensive assessment must

consider whether improvements in efficiency occur alongside improvements in the working conditions and psychological well-being of frontline clinicians.

Despite the growing adoption of Lean methodologies in hospital settings, robust evidence examining their simultaneous effects on operational performance and clinician well-being remains limited. Due to nature of healthcare it becomes very difficult to integrate the principles of lean management as production flow in factories is different from the needs of patients (7). Many prior investigations have measured throughput indicators without systematically evaluating staff burnout, job satisfaction, or work engagement. Furthermore, few studies have employed rigorous experimental designs capable of isolating the effect of management system redesign from other organizational influences (16). Randomized trials, in which clinical units rather than individual patients are randomized to intervention or control conditions, provide a particularly valuable methodology for studying organizational interventions within complex healthcare environments. Such designs allow researchers to evaluate system-level changes while minimizing contamination across clinicians working within the same operational setting.

Given these considerations, a carefully designed evaluation of Lean management implementation within emergency departments is necessary to clarify whether process redesign can simultaneously enhance operational efficiency and support clinician well-being. Understanding this relationship is critical for healthcare administrators seeking sustainable solutions to emergency department crowding while preserving a healthy and engaged workforce.

The present study therefore sought to examine the impact of a comprehensive Lean management system redesign implemented across emergency department care processes. Using a randomized controlled trial design, the study evaluated whether Lean-based operational restructuring improved patient throughput metrics while also influencing levels of clinician burnout and work-related stress. The primary objective was to determine whether systematic workflow redesign could deliver measurable improvements in both emergency department operational efficiency and clinician well-being, thereby informing future strategies for sustainable healthcare quality improvement.

METHODS

A randomized controlled trial with department-level allocation was conducted to evaluate the impact of a Lean management system redesign on emergency department throughput and clinician burnout. The study was carried out across emergency departments in the Islamabad–Rawalpindi region, a major urban healthcare hub characterized by high patient turnover, diverse clinical presentations, and substantial demand for emergency services.

This setting was considered appropriate for examining operational efficiency interventions because hospitals in the region frequently experience crowding and workflow pressures that can influence both patient throughput and clinician workload. The study was conducted over a four-month period from May to August 2025, allowing sufficient time for implementation of workflow modifications and subsequent evaluation of outcomes.

Emergency departments within participating tertiary care hospitals were treated as groups and were randomly assigned to either the Lean management intervention group or the standard operational practice group. Clinicians working within these departments constituted the study participants. Eligible participants included emergency physicians, nurses, and clinical officers who had been working in the department for at least six months prior to the study period and were actively involved in patient care processes such as triage, assessment, or treatment coordination. Individuals working exclusively in administrative roles, interns undergoing short clinical rotations, or staff members planning extended leave during the study period were excluded to maintain consistency in exposure to departmental workflow changes.

A total sample size of 72 clinicians was determined for the study. This number was informed by earlier research examining organizational interventions in emergency departments, where comparable randomized-based studies assessing workflow improvement and staff well-being typically included approximately 60–80 clinical participants. The final sample size allowed balanced representation of clinicians across intervention and control groups while remaining feasible within the operational structure of the participating departments.

The intervention involved the implementation of Lean management principles aimed at reducing process inefficiencies and improving care flow. Key components included value stream mapping of patient pathways, redesign of triage and patient handoff procedures, standardized communication protocols, and brief daily team huddles focused on workflow coordination. Frontline clinicians were actively involved in identifying bottlenecks and suggesting improvements during the initial redesign phase. Departments assigned to the control group continued with their routine operational processes during the study period.

Operational efficiency outcomes were assessed using routinely recorded departmental indicators, including patient waiting time to physician assessment, total emergency department length of stay, and rate of patients leaving without being seen. Clinician well-being was measured using the Maslach Burnout Inventory–Human Services Survey (MBI-HSS), a widely validated instrument assessing emotional exhaustion, depersonalization, and personal accomplishment among healthcare professionals. Additional work-environment perceptions were evaluated using the Copenhagen Psychosocial Questionnaire short form to capture perceived workload, teamwork climate, and job satisfaction.

Data were collected at baseline prior to the intervention and again at the end of the four-month study period. Operational metrics were extracted from hospital information systems, while clinician questionnaires were administered in person to ensure completeness of responses. Data analysis was conducted using statistical software after confirmation of normal distribution through the Shapiro–Wilk test. Continuous variables were summarized using means and standard deviations. Independent t-tests were applied to compare post-intervention outcomes between intervention and control groups, while paired t-tests were used to examine within-group changes from baseline. Analysis of variance (ANOVA) was employed where comparisons involved more than two clinical roles, and Pearson correlation analysis was performed to explore relationships between operational metrics and burnout scores. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 78 eligible clinicians working within the participating emergency departments were initially approached for inclusion in the study. Of these, 72 clinicians consented and completed baseline assessment, resulting in a response rate of 92.3%. All enrolled participants remained in their assigned departmental departments throughout the study period and completed the follow-up assessment at four months, yielding a final analytic sample of 72 clinicians. The intervention departments included 36 clinicians exposed to the Lean management system redesign, while 36 clinicians continued working under standard operational procedures in the control departments. Operational throughput data were available for all departments across the entire study period.

The demographic and professional characteristics of participants are summarized in Table 1. The overall mean age of clinicians was 33.8 ± 5.7 years, with a slight predominance of male participants (54.2%). Nurses constituted the largest professional group (44.4%), followed by emergency physicians (34.7%) and clinical officers (20.8%). The mean duration of clinical experience in emergency care was 7.1 ± 3.4 years. Baseline demographic characteristics were comparable between the intervention and control departments, with no statistically significant differences observed in age distribution, gender composition, or professional role.

Operational efficiency indicators demonstrated measurable improvements within departments implementing the Lean management redesign. The mean patient waiting time to physician assessment decreased from 41.6 ± 9.3 minutes at baseline to 28.7 ± 7.4 minutes following implementation in intervention departments, while control departments showed only a modest reduction from 40.9 ± 8.8 minutes to 38.5 ± 8.1 minutes.

The between-group difference at follow-up was statistically significant (p = 0.002). Similarly, the average emergency department length of stay declined from 196.4 ± 34.5 minutes to 158.2 ± 30.6 minutes in the intervention group, compared with 192.1 ± 31.9 minutes to 187.6 ± 29.7 minutes in the control group (p = 0.001). The proportion of patients leaving without being seen also decreased more prominently in intervention departments (3.8% vs. 6.5% in controls). These findings are presented in Table 2.

Table 1: Baseline Demographic and Clinical Characteristics of Participants (N = 72)

Variable	Categories	n (%) / Mean ± SD
Age (years)	Mean ± SD	33.8 ± 5.7
Gender	Male	39 (54.2%)
	Female	33 (45.8%)
Professional Role	Emergency Physician	25 (34.7%)
	Nurse	32 (44.4%)
	Clinical Officer	15 (20.8%)
Years of Emergency Care Experience	Mean ± SD	7.1 ± 3.4
Department Allocation	Lean Intervention group	36 (50.0%)
	Control group	36 (50.0%)

Table 2: Emergency Department Operational Throughput Outcomes

Outcome Variable	Intervention Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
Waiting Time to Physician (minutes)	28.7 ± 7.4	38.5 ± 8.1	0.002
Emergency Department Length of Stay (minutes)	158.2 ± 30.6	187.6 ± 29.7	0.001
Patients Leaving Without Being Seen (%)	3.8 ± 1.2	6.5 ± 1.9	0.009

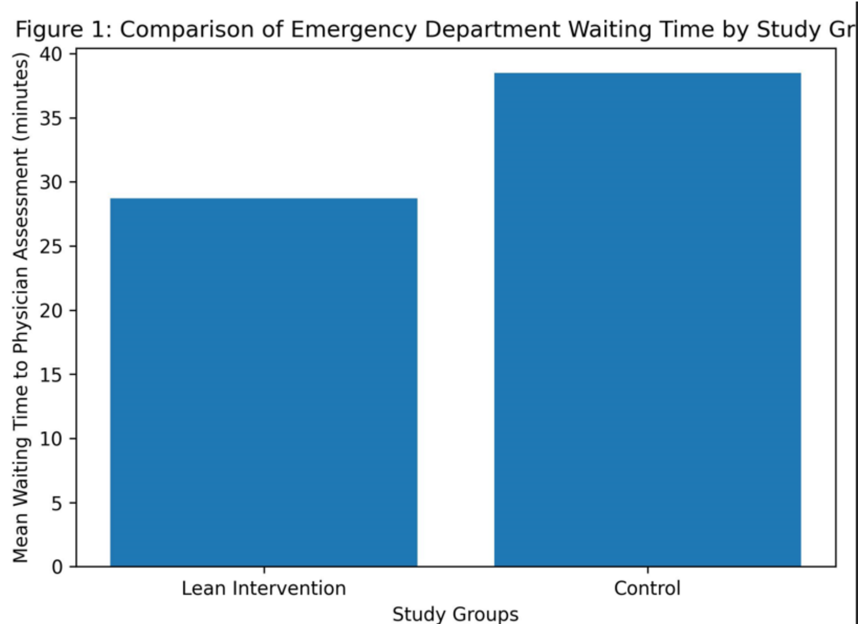
Table 3: Maslach Burnout Inventory Domain Scores

Burnout Domain	Intervention Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
Emotional Exhaustion	22.6 ± 6.3	26.4 ± 6.5	0.004
Depersonalization	8.9 ± 3.1	10.7 ± 3.6	0.018
Personal Accomplishment	34.2 ± 5.8	31.1 ± 6.2	0.011

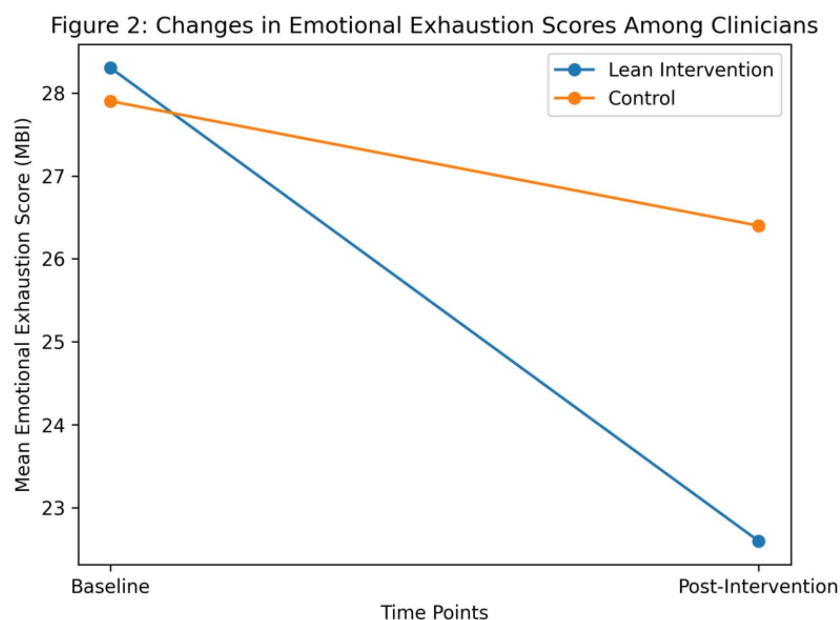
Table 4: Pearson Correlation Between Operational Metrics and Burnout Scores

Variable Pair	Correlation (r)	p-value
Waiting Time vs Emotional Exhaustion	−0.42	0.001
Length of Stay vs Depersonalization	−0.36	0.004
Waiting Time vs Personal Accomplishment	−0.28	0.019

Clinician well-being outcomes also showed meaningful differences between groups. Mean emotional exhaustion scores measured using the Maslach Burnout Inventory decreased from 28.3 ± 7.1 to 22.6 ± 6.3 among clinicians in intervention departments, whereas control departments demonstrated only a slight reduction from 27.9 ± 6.8 to 26.4 ± 6.5. The between-group difference at follow-up reached statistical significance ($p = 0.004$). Depersonalization scores also declined modestly in the intervention group ($p = 0.018$), while personal accomplishment scores increased significantly compared with the control group ($p = 0.011$). Detailed burnout domain scores are presented in Table 3.



Further analysis explored the relationship between operational performance indicators and clinician burnout dimensions. Pearson correlation analysis revealed that shorter patient waiting times were moderately associated with lower emotional exhaustion scores ($r = -0.42$, $p = 0.001$). Similarly, reduced emergency department length of stay demonstrated a negative correlation with depersonalization scores ($r = -0.36$, $p = 0.004$). These findings suggested that improvements in departmental workflow were linked with improved clinician well-being metrics. Comparative outcome analysis between departments is summarized in Table 4.



Overall, departments implementing Lean-based workflow redesign experienced improvements in both operational throughput indicators and clinician burnout outcomes. The magnitude of change was consistently greater in intervention departments compared with departments maintaining standard operational procedures, indicating that system-level process redesign may simultaneously enhance efficiency and workforce well-being within high-demand emergency care environments.

DISCUSSION

The present study examined the impact of a Lean management system redesign on both operational performance and clinician well-being within emergency department settings (17). The findings indicated that departments implementing Lean-based workflow restructuring demonstrated meaningful improvements in patient throughput indicators while simultaneously showing reductions in clinician burnout scores. These outcomes suggest that carefully implemented operational redesign can influence not only efficiency metrics but also the work experience of frontline healthcare professionals. In environments such as emergency departments, where time pressure and workflow complexity frequently converge, organizational structures appear to play a crucial role in shaping both patient flow and staff psychological outcomes (18).

The reduction in patient waiting time and overall emergency department length of stay observed in the intervention groups reflects the potential value of structured process improvement strategies in high-demand clinical environments (19). Lean management emphasizes identification of inefficiencies within care pathways, allowing teams to remove unnecessary steps and streamline transitions between stages of care. The improvements recorded in the current study were consistent with earlier observations from hospital systems that adopted similar workflow redesign initiatives. In those settings, structured triage modifications, standardized communication processes, and coordinated team huddles contributed to faster patient assessment and improved coordination between clinical staff (20). The current findings reinforced the idea that operational bottlenecks within emergency departments often arise from fragmented processes rather than purely from insufficient resources.

Beyond improvements in throughput metrics, the observed reductions in emotional exhaustion and depersonalization among clinicians provided an important perspective on the human consequences of operational design. Emergency medicine professionals frequently operate under intense cognitive and emotional demands, and prolonged exposure to chaotic workflow conditions can accelerate burnout (21). The intervention departments in this study experienced measurable reductions in emotional exhaustion scores, suggesting that improved workflow clarity and better team coordination may reduce the mental

strain associated with unpredictable patient flow (22). When clinicians are able to navigate structured processes with fewer interruptions and ambiguities, their capacity to focus on clinical decision-making may improve, which in turn contributes to greater professional satisfaction.

The relationship identified between operational indicators and burnout measures further supported the interconnected nature of system performance and clinician well-being. Shorter patient waiting times were associated with lower emotional exhaustion scores, while reduced department length of stay correlated with lower depersonalization levels (23). These patterns suggested that inefficiencies within care delivery systems may indirectly contribute to psychological strain among clinicians. When clinicians repeatedly encounter delays, overcrowding, and administrative obstacles, their professional engagement can gradually erode (24). Conversely, streamlined systems appear to support a more manageable work environment, reinforcing the idea that quality improvement initiatives should consider staff well-being as a core outcome rather than a secondary benefit.

Despite these encouraging findings, the interpretation of the results requires careful consideration of the study's scope. The randomized design represented a methodological strength, as it allowed evaluation of a system-level intervention within natural clinical settings while minimizing contamination between groups. The inclusion of both operational performance indicators and validated burnout measurement tools also strengthened the analytical framework, enabling simultaneous assessment of organizational and psychological outcomes. Furthermore, the active involvement of frontline clinicians in identifying workflow challenges during the Lean redesign process likely contributed to practical and contextually relevant improvements within the departments.

Several limitations nevertheless warrant acknowledgment. The study was conducted within a limited number of emergency departments in a single urban healthcare region, which may restrict the generalizability of the findings to other hospital systems with different organizational structures or patient demographics. The relatively short duration of follow-up also limited the ability to determine whether the observed improvements in efficiency and clinician well-being would be sustained over longer periods. Organizational interventions often require continuous reinforcement, and it remains possible that initial gains may diminish if ongoing process evaluation and staff engagement are not maintained. In addition, while validated self-report instruments were used to measure burnout, responses may still have been influenced by social or professional perceptions within the workplace.

The modest sample size represented another practical constraint inherent to randomized-based studies within clinical environments. While the sample was sufficient to detect statistically meaningful differences in key outcomes, larger multi-center investigations would provide stronger evidence regarding the broader applicability of Lean management interventions in emergency medicine settings. Future research may also benefit from examining additional dimensions of clinician well-being, including job satisfaction, teamwork climate, and turnover intentions. Exploring patient-centered outcomes such as satisfaction, safety indicators, and clinical effectiveness could further enrich understanding of how operational redesign influences the overall quality of emergency care.

Taken together, the findings highlighted the potential for structured management approaches to address both operational inefficiencies and workforce challenges within emergency departments. Healthcare systems increasingly recognize that sustainable performance improvement requires attention to both organizational processes and the human experience of clinical work. Interventions that successfully integrate these dimensions may offer a pathway toward emergency care environments that are not only more efficient but also more supportive for the professionals who deliver care under demanding conditions.

CONCLUSION

The findings demonstrated that Lean-based management system redesign within emergency departments was associated with meaningful improvements in operational efficiency and clinician well-being. Departments implementing structured workflow optimization experienced shorter patient waiting times, reduced overall length of stay, and lower levels of clinician burnout compared with standard operational practices. These results highlighted the potential of system-level process improvement strategies to address both performance challenges and workforce strain. Integrating operational redesign with staff-centered quality improvement may represent a practical pathway toward more efficient and sustainable emergency care delivery.

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