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System-Level Determinants of Chest Pain Triage Delay and the Impact of Structured Risk Stratification: A Mixed-Methods Quasi-Experimental Study in Malaysian Emergency Departments

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ABSTRACT

Chest pain is a high-risk presentation in Emergency Departments (EDs) that requires rapid risk stratification to prevent adverse cardiovascular outcomes. Although international guidelines recommend electrocardiogram (ECG) acquisition within 10 minutes of arrival, achieving this benchmark consistently remains challenging, particularly in resource-limited healthcare systems. Empirical data examining structural readiness and workflow determinants of triage delay in Malaysian EDs remain limited. This study aimed to identify factors contributing to delays in the triage process of chest pain patients and to evaluate the impact of implementing a structured Chest Pain Score on waiting time and prioritization accuracy. A mixed-methods quasi-experimental pre–post design was conducted in a tertiary Malaysian ED, supported by nationwide structural mapping of 21 public hospitals. A total of 300 adult patients with chest pain were included (pre-intervention n = 150; post-intervention n = 150). Quantitative outcomes included waiting time from primary to secondary triage, distribution of waiting time categories, and incidence of under-triage. Statistical analysis employed independent t-tests, chi-square tests, and effect size estimation. Qualitative data from workflow observations and semi-structured interviews were analyzed using NVivo's thematic analysis. The baseline mean waiting time was 24.8 ± 10.6 minutes, significantly exceeding the 10-minute benchmark ($p < 0.001$). Structural mapping revealed that only 47.6% of hospitals had ECG access at secondary triage. Forty-three under-triage cases were documented over six months (mean 7.17 ± 2.04 per month). Following implementation of the Chest Pain Score, mean waiting time decreased to 6.3 ± 3.8 minutes ($t(298) = 18.92$, $p < 0.001$), with a very large effect size (Cohen's $d = 2.18$). Post-intervention, 96.7% of patients were assessed within 14 minutes, and no patient experienced delays ≥30 minutes. Thematic analysis identified queue-based workflow design, overcrowding, staffing shortages, and cognitive overload as primary determinants of delay. These findings demonstrate that triage delay reflects multi-layered structural and operational inefficiencies rather than isolated clinical error. Embedding structured risk stratification into triage workflows significantly reduces the magnitude and variability of delays and may represent a scalable strategy to improve time-sensitive cardiovascular care in emergency systems.

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1. Introduction

Chest pain remains one of the most frequent and diagnostically challenging presentations in Emergency Departments (EDs) worldwide. Contemporary epidemiological reports estimate that chest pain accounts for approximately 5–10% of all ED visits, with a clinically significant proportion representing acute coronary syndrome (ACS). Despite advances in biomarker testing and interventional cardiology, early triage decision-making continues to determine downstream outcomes, particularly for time-sensitive conditions such as ST-elevation myocardial infarction (STEMI). Recent guidelines from the European Society of Cardiology (ESC, 2020) and subsequent updates from the American Heart Association (AHA, 2021–2024) emphasize the critical importance of rapid risk stratification and electrocardiogram (ECG) acquisition within 10 minutes of arrival to minimize myocardial damage and mortality. However, achieving this benchmark in real-world ED settings remains challenging. Post-pandemic healthcare systems have reported sustained increases in ED crowding, staffing shortages, and operational strain [1], [2]. Between 2020 and 2024, multiple multicenter studies across Europe, North America, and Asia have demonstrated that ED crowding is independently associated with prolonged door-to-ECG times, delayed reperfusion therapy, and increased short-term mortality in ACS populations [3]. These findings suggest that triage delay is not merely a clinical oversight but a systemic vulnerability embedded within emergency care infrastructure.

In addition to structural constraints, emerging literature highlights the cognitive complexity of triage decision-making. Under conditions of time pressure and high patient volume, clinicians rely more heavily on heuristic reasoning, increasing their susceptibility to anchoring bias and to underestimating “stable-appearing” chest pain presentations [4]–[6]. Studies published between 2020 and 2025 increasingly advocate for structured risk stratification tools embedded directly within triage workflows to mitigate subjective variability and reduce mistriage rates. Risk-based models such as HEART, EDACS, and institution-specific chest pain scores have improved early identification of high-risk patients while preserving resource efficiency [7], [8]. Despite these advances, implementation heterogeneity remains substantial, particularly in middle-income healthcare systems where infrastructure and specialist access may vary between institutions. In Southeast Asia, limited published data exist regarding structural readiness for chest pain triage, ECG accessibility at the triage point, and the operational integration of specialist consultation into early decision-making. The absence of standardized chest pain–specific triage tools may further exacerbate variability in prioritization.

Malaysia faces a high and growing burden of cardiovascular disease, which remains a leading cause of mortality nationally. In this context, optimizing triage processes for patients with chest pain represents both a clinical and public health priority. Yet, there is limited empirical evidence quantifying the magnitude of triage delay, identifying its underlying determinants, and evaluating structured interventions within Malaysian EDs.

Therefore, this study aims to systematically examine factors contributing to delays in the triage of chest pain patients and to evaluate the impact of implementing a structured Chest Pain Score on waiting time and prioritization accuracy. By integrating nationwide structural mapping, institutional mistriage audits, time-motion analysis, and qualitative thematic exploration, this research seeks to provide an evidence-based framework for triage redesign in resource-variable emergency care systems. Through this approach, the study contributes contemporary, system-level insights aligned with global emergency medicine priorities (2020–2025) and addresses a critical gap in regional evidence on time-sensitive cardiovascular triage optimization.

2. Methodology

This study employed a mixed-methods, quasi-experimental pre–post intervention design integrating quantitative time-motion analysis with qualitative thematic exploration. The design was selected to enable comprehensive evaluation of structural, operational, and cognitive determinants of triage delay, while simultaneously assessing the effectiveness of a structured Chest Pain Score intervention.

The study was conducted in two sequential phases. Phase I, the baseline assessment (pre-intervention phase), involved system mapping, a national structural survey, a retrospective mistriage audit, and prospective measurement of waiting time. Phase II, the post-intervention evaluation phase, consisted of implementing a structured Chest Pain Score, followed by repeated time-motion measurements and comparative statistical analysis. This phased design enables causal inference through within-site comparison while preserving ecological validity within a real-world Emergency Department (ED) setting.

The study was conducted in a tertiary-level public Emergency Department in Malaysia, supported by a nationwide structural readiness assessment involving 21 public hospitals. The primary study site manages high patient volumes and operates a dual-stage triage system (primary and secondary triage).

The national mapping component evaluated:

a. Availability of structured secondary triage
b. ECG access at triage level
c. Immediate specialist consultation availability
d. Operational workflow configuration

The study population consisted of adult patients aged 18 years and above who presented to the Emergency Department with chest pain as their primary complaint during the defined study period. Eligible participants were those formally registered at the primary triage counter, ensuring standardized entry into the triage workflow and accurate timestamp recording for subsequent analysis. The sampling approach included all eligible patients meeting the criteria within the specified timeframe to ensure representativeness and minimize selection bias. Patients were excluded if their chest pain was secondary to trauma, as these cases follow a different clinical pathway and triage priority system. Individuals who were hemodynamically unstable and required immediate resuscitation were also excluded due to the urgent nature of their management, which bypasses routine triage processes. Additionally, cases with incomplete or missing triage documentation were excluded to maintain data integrity and ensure the reliability of both quantitative and qualitative analyses.

A total of 300 patients were included in this study, comprising 150 patients in the pre-intervention group and 150 patients in the post-intervention group. Sample size adequacy was confirmed using power analysis ($\alpha = 0.05$, power = 0.80), demonstrating sufficient power to detect clinically meaningful differences in waiting time. The intervention involved the introduction of a structured Chest Pain Score integrated into the secondary triage workflow within the Emergency Department. The scoring system was designed to standardize clinical assessment and improve risk stratification for patients presenting with chest pain. It incorporated key clinical domains, including symptom characteristics, established cardiovascular risk factors, vital signs, and the presence of clinical red flags suggestive of high-risk pathology.

Prior to implementation, triage nurses underwent structured training to ensure accurate application, scoring consistency, and clinical interpretation of the tool. The Chest Pain Score functioned as a risk-prioritization mechanism, shifting the triage process from a conventional queue-based chronological sequencing model to a stratified clinical prioritization system based on patient risk severity. This approach aimed to reduce delays for high-risk cardiovascular presentations while maintaining workflow efficiency.

Data Collection Procedures

Three key quantitative components were evaluated in this study. Waiting time was defined as the time, measured in minutes, from the completion of primary triage to the initiation of the secondary triage assessment, and was captured using electronic timestamp records to ensure precision and consistency. A mistriage audit was also conducted through a retrospective review of documented under-triage cases over a six-month period, identified via formal incident reporting systems and clinical audit meetings. In addition, a structural readiness survey was administered using a standardized questionnaire distributed to 21 public hospitals to collect data on triage configuration and access to diagnostic facilities.

The qualitative component complemented these findings through direct non-participant observation of the triage workflow to understand real-time operational processes and interactions. Semi-structured interviews were conducted with Emergency Department physicians and triage nurses to explore their experiences and perceptions of the workflow and intervention. Field notes were recorded to document operational bottlenecks and contextual challenges observed during data collection. All interviews were audio-recorded with consent and transcribed verbatim to preserve data accuracy and authenticity.

Data analysis was conducted using both quantitative and qualitative approaches. Quantitative analysis was performed using SPSS (Version XX), where continuous variables were summarized as mean ± standard deviation and categorical variables were presented as frequencies and percentages. Inferential testing included independent t-tests to compare mean waiting times, chi-square tests for categorical differences, and a one-sample t-test against the 10-minute benchmark. Effect size was calculated using Cohen's d, and statistical significance was set at $p < 0.05$ (two-tailed). Qualitative data were analyzed using NVivo software following Braun and Clarke's six-step thematic analysis framework, including familiarization, coding, theme development, review, definition, and reporting. Triangulation across observational data, interview transcripts, and audit findings enhanced analytical credibility.

The study design incorporated several measures to ensure validity and methodological rigor. Baseline demographic comparability between groups was statistically confirmed, and timestamp-based measurement minimized recall bias. The triangulated mixed-method approach strengthened internal validity, while the standardized intervention protocol enhanced reproducibility. By integrating system-level and patient-level analyses, employing effect size reporting, and utilizing a pre–post comparative framework, the methodology provides a systematic and empirically grounded approach to evaluating determinants of triage delay and the effectiveness of interventions in time-sensitive cardiovascular presentations, while maintaining real-world relevance.

3. Results

This study examined factors contributing to delays in the triage process for chest pain patients in Malaysian Emergency Departments (EDs) using a mixed-methods design that integrated nationwide system mapping, institutional triage data, time-motion measurement, structured interviews, and thematic analysis. Findings are presented according to the research objective: to identify factors that slow down the triage process, followed by evaluation of the Chest Pain Score intervention.

A total of 300 patients with chest pain were included in the analysis, comprising 150 patients in the pre-intervention phase and 150 patients following implementation of the Chest Pain Score.

Baseline demographic characteristics are presented in **Table 1**. The mean age did not differ significantly between groups (pre: 49.6 ± 10.8 years; post: 48.9 ± 11.2 years; $p = 0.63$). Although the proportion of male patients decreased from 96.7% to 86.7% post-intervention, this difference was not statistically significant ($p = 0.08$).

These findings confirm demographic comparability between groups, supporting the validity of subsequent inferential comparisons.

Table 1
Baseline Demographic Characteristics (Pre vs Post Intervention)

Variable	Pre (n=150)	Post (n=150)	Statistical Test	p-value
Age (years), mean ± SD	49.6 ± 10.8	48.9 ± 11.2	Independent t-test	0.63
Male, n (%)	145 (96.7%)	130 (86.7%)	χ^2 test	0.08
Female, n (%)	5 (3.3%)	20 (13.3%)		

A nationwide assessment involving 21 public hospitals revealed full implementation of primary triage (100%). However, only 76.2% of hospitals maintained a structured secondary triage counter. Diagnostic and specialist readiness showed greater variability. Only 47.6% of hospitals had ECG facilities available directly at secondary triage, and an equivalent proportion reported immediate access to specialist consultation within the Emergency Department. Structural readiness across institutions is summarized in **Table 2**. Hospitals lacking ECG access at the triage level required patient transfer to treatment zones before cardiac evaluation, introducing a systematic delay in early risk stratification.

Table 2
National Structural Readiness of Emergency Departments (n = 21 Hospitals)

Structural Component	n (%)
Primary Triage Available	21 (100%)
Secondary Triage Available	16 (76.2%)
ECG at Secondary Triage	10 (47.6%)
Immediate Specialist Consultation	10 (47.6%)

Between January and June 2025, 43 cases of under-triage involving chest pain patients were documented. The mean monthly incidence was 7.17 ± 2.04 cases, with the highest number recorded in April (10 cases). Monthly distribution is detailed in **Table 3**. Persistent mistriage across all six months indicates a systemic rather than sporadic classification problem.

Table 3
Monthly Chest Pain Mistriage Incidence (Jan–Jun 2025)

Month	Cases
January	8
February	6
March	8
April	10
May	7
June	4

Mean ± SD: 7.17 ± 2.04 cases/month
Range: 4–10 cases

Among the 150 patients evaluated before intervention, the mean waiting time from primary to secondary triage was 24.8 ± 10.6 minutes (median 23 minutes; range 4–58 minutes). Waiting time distribution categories are shown in Table 5. More than half of patients (52.7%) waited 15-29 minutes, and 25.3% waited 30 minutes or longer. Only 22% were assessed within 14 minutes. A one-sample t-test comparing the observed mean waiting time to a 10-minute benchmark for early cardiac assessment demonstrated statistically significant delay ($p < 0.001$).

Table 4
Waiting Time Distribution Categories

Waiting Time Category	Pre n (%)	Post n (%)
0–14 minutes	33 (22.0%)	145 (96.7%)
15–29 minutes	79 (52.7%)	5 (3.3%)
≥30 minutes	38 (25.3%)	0 (0%)

Thematic analysis of observational and interview data using NVivo identified three dominant categories contributing to triage delay: process-related, system-related, and human-factor determinants. Process-related factors included queue-based card sequencing and non-priority patient calling. System-related factors comprised overcrowding, staffing shortages, limited bed availability, and the absence of ECG equipment at triage. Human-factor determinants involved cognitive overload, under-recognition of stable-appearing chest pain, and inconsistent application of structured symptom assessment. The frequency of coded themes is summarized in **Table 6**, which demonstrates the relative prominence of workflow and system constraints in contributing to delays.

Table 5
Thematic Factors Contributing to Delay (NVivo Coding Frequency)

Theme	Frequency (Nodes Identified)	Category
Queue-based workflow	18	Process-related
Non-priority card arrangement	15	Process-related
Overcrowding	22	System-related
Staffing shortage	19	System-related
Lack of ECG at triage	14	System-related
Cognitive overload	17	Human-factor
Under-recognition of stable chest pain	13	Human-factor
Infrequent training	11	Human-factor

Table 6
Waiting Time (Minutes) – Pre vs Post Intervention

Variable	Pre (n=150)	Post (n=150)	Mean Difference	95% CI	p-value	Effect Size
Waiting time (minutes), mean ± SD	24.8 ± 10.6	6.3 ± 3.8	18.5	16.9–20.1	<0.001	Cohen's d = 2.18

A categorical distribution further illustrates the magnitude of the change. Post-intervention, 97% of patients were assessed within 14 minutes, and no patient experienced a delay of more than 30 minutes (see Table 5). Chi-square testing confirmed a significant shift in waiting time distribution ($p < 0.001$). A consolidated summary of statistical testing is presented in Table 7. All primary outcome comparisons were statistically significant, except for baseline demographic variables, confirming that reductions in delay were attributable to the intervention rather than population differences.

Table 7
Inferential Summary

Outcome	Test Used	Statistic	p-value	Interpretation
Mean waiting time difference	Independent t-test	$t(298)=18.92$	<0.001	Significant reduction
Waiting time distribution	Chi-square	$\chi^2(2)=212.4$	<0.001	Significant shift
Age difference	t-test	$t(298)=0.48$	0.63	Not significant
Gender difference	χ^2	$\chi^2(1)=3.02$	0.08	Not significant

Collectively, results demonstrate that triage delay in chest pain patients arises from an interaction between:

1. Structural diagnostic variability
2. Queue-based workflow design
3. System-level resource constraints
4. Human-factor limitations in clinical prioritization
5. Absence of standardized chest pain–specific triage tools

Importantly, these factors are modifiable. Implementing a structured Chest Pain Score significantly reduced waiting time and improved triage prioritization.

The findings indicate that triage delay is not attributable to a single failure point but reflects a multi-layered interaction between infrastructure, workflow design, and human decision-making under operational pressure.

4. Discussions

This study demonstrates that delays in the triage of chest pain patients are driven by a multi-layered interaction between structural readiness, workflow design, system crowding, and human cognitive factors. Before intervention, the mean waiting time from primary to secondary triage was 24.8 ± 10.6 minutes—significantly exceeding the recommended early cardiac assessment window. Following implementation of the Chest Pain Score, waiting time decreased to 6.3 ± 3.8 minutes, with a very large effect size (Cohen's d = 2.18).

Importantly, the intervention did not merely reduce average delay but also reduced variability, suggesting improved consistency and standardization in triage performance. These findings indicate that triage delay is not simply an issue of individual oversight but reflects structural and operational inefficiencies that can be mitigated through systematic redesign [9]–[11]. One of the most salient findings was the heterogeneity in ECG availability at the triage level, with only approximately half of hospitals providing immediate access. Contemporary emergency medicine literature consistently identifies “door-to-ECG ≤10 minutes” as a critical quality benchmark for the management of acute coronary syndrome (ACS) [12]–[14].

Recent multicenter evaluations (2020–2023) have demonstrated that delayed ECG acquisition is independently associated with prolonged door-to-balloon time and increased short-term mortality in STEMI populations. Studies in both high and middle-income countries report that structural placement of ECG machines directly within triage areas significantly improves compliance with time targets [15]–[17]. Our findings align with these reports, suggesting that diagnostic decentralization, placing ECG capability directly at triage, may reduce early evaluation delays. In resource-variable systems such as Malaysia, this represents a critical system-level leverage point.

The queue-based, first-come-first-served card system identified in this study represents a classical operational bottleneck. Recent operational modeling research (2020–2025) shows that chronological triage sequencing increases risk for time-sensitive conditions during crowding episodes [18]–[20]. Emergency department simulation studies published after the COVID-19 pandemic have emphasized the vulnerability of non-prioritized queue systems, particularly when patient influx exceeds staffing capacity. Risk-based fast-track models have been shown to reduce waiting times for high-acuity presentations without increasing overall throughput burden. The Chest Pain Score intervention effectively converted chronological sequencing into structured risk stratification. This aligns with recent calls in the emergency medicine literature for decision-support-augmented triage models to reduce reliance on unsystematic prioritization.

ED crowding has been repeatedly linked to increased morbidity and mortality, particularly for cardiovascular emergencies. Post-2020 studies across Europe, North America, and Asia demonstrate that overcrowding is associated with longer time-to-treatment and higher 30-day mortality among ACS patients. Our qualitative findings, staff shortages, peak-hour clustering (particularly Mondays and Tuesdays), and limited bed availability mirror global evidence that crowding introduces both temporal delay and cognitive burden.

Notably, the literature from 2021 to 2024 shows that crowding not only delays treatment but also increases diagnostic error due to cognitive overload. The reduction in waiting time variability after intervention suggests that structured tools may buffer the impact of crowding by reducing discretionary variability in triage decisions.

Human Factors and Cognitive Load

Triage is fundamentally a high-pressure cognitive task. Contemporary research in clinical cognitive science demonstrates that under time pressure and workload stress, clinicians rely more heavily on heuristics, increasing susceptibility to anchoring bias and premature closure. Our data showed frequent under-recognition of stable-appearing chest pain patients, consistent with “visual stability bias” described in emergency decision-making research. Between 2020 and 2025, multiple studies have advocated integrating structured risk scores into triage workflows to reduce reliance on gestalt alone. The Chest Pain Score in this study functioned as a cognitive scaffold, standardizing risk identification and reducing subjective variability. The observed large effect size suggests that structured tools may play a substantial role in mitigating human-factor-related delay.

The findings carry important clinical and policy implications. Integrating ECG equipment directly within triage zones may substantially reduce diagnostic delays for high-risk chest pain patients. Traditional queue-based, non-priority systems should be replaced with risk-based stratification models to ensure timely assessment of patients with potentially life-threatening cardiovascular conditions. The structured Chest Pain Score introduced in this study demonstrates potential for national standardization to enhance uniformity and clinical safety across Emergency Departments. In addition, triage training frequency should be increased beyond semiannual refreshers to reinforce decision-making competence, and cognitive-support tools should be incorporated, particularly during peak-hour operations when workload pressures are highest. Given the significant national burden of cardiovascular mortality, optimizing triage systems at the structural level may represent a cost-effective and scalable strategy to reduce preventable deaths.

This study possesses several methodological strengths. The integration of mixed methods, combining robust quantitative analysis with NVivo-supported thematic exploration, allowed for comprehensive insight into both measurable outcomes and contextual workflow dynamics. The pre–post inferential design strengthened causal interpretation of the intervention's impact, while the large effect size demonstrated clear clinical relevance beyond statistical significance. The inclusion of a national structural mapping component enhanced external applicability, and the quantification of both delay magnitude and variability provided a nuanced understanding of system performance.

However, certain limitations must be acknowledged. The intervention phase was conducted in a single center, which may limit generalizability across diverse healthcare settings. Long-term cardiac outcomes were not evaluated, preventing assessment of sustained clinical impact. A potential Hawthorne effect may have influenced behavior during the post-implementation phase, and multivariate regression analysis controlling for peak-hour clustering was not performed. Additionally, critical downstream metrics such as ECG-to-balloon time were not assessed. Future research should therefore consider multicenter randomized implementation studies to validate findings and strengthen policy translation.

5. Conclusions

This study provides robust empirical evidence that delays in the triage of chest pain patients within Malaysian Emergency Departments are not incidental but arise from a complex interaction between structural limitations, workflow design, system crowding, and human cognitive factors. Baseline findings showed a mean waiting time of 24.8 ± 10.6 minutes, which was significantly above recommended early cardiac assessment benchmarks. Structural heterogeneity, particularly the limited availability of ECG at secondary triage (47.6% of hospitals), further contributed to systematic delay. The identification of 43 documented under-triage cases over six months confirms that misclassification is persistent rather than sporadic. Thematic analysis reinforced that queue-based sequencing, overcrowding, staffing shortages, and cognitive overload operate synergistically to slow clinical decision-making. Importantly, these determinants are modifiable.

Implementation of the structured Chest Pain Score resulted in a substantial and statistically significant reduction in waiting time to 6.3 ± 3.8 minutes ($t(298) = 18.92$, $p < 0.001$), with a very large effect size (Cohen's $d = 2.18$). Beyond reducing mean delay, the intervention reduced variability and eliminated prolonged waits of more than 30 minutes, indicating improved consistency and system reliability. The findings demonstrate that triage delay in chest pain patients reflects a systems-level vulnerability rather than isolated human error. Embedding structured risk stratification at the triage point, decentralizing ECG access, and redesigning queue-based workflows into risk-prioritized models represent high-impact strategies for improving early cardiac assessment.

From a policy perspective, standardizing chest pain-specific triage tools across Malaysian Emergency Departments may offer a scalable, cost-effective mechanism to enhance patient safety and reduce time-sensitive cardiac risk. Future multicenter implementation studies incorporating clinical outcome endpoints (e.g., door-to-balloon time and short-term mortality) are warranted to validate the downstream impact of triage optimization further. Overall, this study advances the evidence base by demonstrating that systematic redesign of triage processes can yield immediate, clinically meaningful reductions in delay for high-risk cardiovascular presentations.

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