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REVIEW ARTICLE

The effect of emergency department overcrowding on patient care outcomes: Insights from a systematic review and meta-analysis

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Abstract

In many nations, overcrowding in emergency departments (EDs) is a serious public health issue that threatens the proper operation of health systems. Understanding the connection between overcrowding and delays in ED treatment provides decision-makers with valuable insights into the problem and supports the implementation of timely solutions. This meta-analysis adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses standards and focuses on evaluating the impact of overcrowding in emergency departments (EDs) on patient care outcomes. Specifically, it synthesizes existing data to identify both the causes of ED overcrowding and its effects on patient outcomes. This review screened 11 articles published between 2010 and 2024, including a total of 3,084,344 patients. Among them, 14.7% were admitted to hospitals, with 49% male and 51% female. The average age was 35.9 years, ranging from 3.9 to 58 years, with a median age of 37.3 years. The minimum waiting time before the first examination was 30 min, with a maximum of 360 min and a mean of 234.0 ± 21.7 min. The total length of stay (LOS) in the ED ranged from 123.5 to 540.0 min, with a mean of 245.8 ± 95.9 min. Most patients were discharged home (67.6%), while 10.9% returned to the ED due to unresolved or worsening conditions. Additionally, 2.31% of patients died, 1.88% eloped, 3.08% left without being seen (LWBS), and 1.27% required ICU admission. This meta-analysis highlights the pervasive impact of ED overcrowding on patient outcomes, healthcare worker well-being, and care quality. Overcrowding prolongs waiting times and LOS, disproportionately affects low-acuity cases, and compromises critical care for high-severity patients. Adverse events, such as LWBS, revisits, and incomplete assessments, are consistently linked to overcrowded conditions. Healthcare workers experience significant stress and burnout, which contributes to medical errors and reduced service efficiency.

Keywords: Emergency department; Overcrowding; Triage; Patient care outcomes

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1. Introduction

Emergency departments (EDs) play a critical role in healthcare systems, providing immediate medical care to patients with urgent and life-threatening conditions. However, ED overcrowding has emerged as a significant public health crisis worldwide,

straining healthcare resources, prolonging waiting times, and compromising patient outcomes. This issue is exacerbated by factors such as rising patient volumes, limited hospital capacity, inefficient triage systems, and workforce shortages.[1]

While previous studies have explored the impacts of overcrowding, the specific effects on patient care outcomes, mortality, and hospital admission rates remain a critical concern.[2,3] Some research suggests that overcrowding increases the rate of adverse events, including delayed treatment, patients leaving without being seen (LWBS), and even increased mortality rates. Additionally, ED congestion contributes to healthcare worker stress and burnout, further affecting service efficiency.[3,4]

Patient deaths have been identified as a significant negative consequence of overcrowding, which serves as a measure of the standard of treatment. Several studies have analyzed databases comparing the death rates of patients treated during congestion periods to those treated during non-congestion periods.[4,5] The majority of these studies indicate that mortality rates are higher during overcrowding and reveal a clear association between increased mortality rates and ED overcrowding. A few systematic reviews have also examined the impact of overcrowding on patient mortality, referencing several studies on this association. However, these reviews have notable limitations and do not provide comprehensive findings.[6] The current review and meta-analysis aim to provide a comprehensive evaluation of how ED overcrowding influences patient care outcomes, including mortality rate, waiting durations, admission patterns, and revisits to the ED. By analyzing data from multiple studies, we seek to offer evidence-based insights to guide healthcare policy and improve emergency care protocols.

2. Methods

The methodological techniques used in this review were outlined in subsequent sections. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards were followed in reporting this review.[7]

2.1. Search strategy

A literature search was performed using MEDLINE, the Cochrane Collaboration Library, EMBASE, Web of Science, Clinicaltrial.gov, and the International Clinical Trials Registry Platform to screen publications between January 2010 and August 2024. The search terms or "MeSH" (Medical Subject Headings) were "emergency department," "emergency service," "accident and emergency," "emergency room, ER," "crowding," "overcrowding," "emergency medical services," "treatment delays," "casualty," "accident & emergency department," and "time to treatment," or a mix of these. Additionally, publications were identified by a manual search of the chosen studies' reference lists. Language, time, and population size were all unrestricted. We also looked through all of the pertinent articles' reference lists to get more details. Although PRISMA guidelines indicate that there are no limits to either date or language when searching,[8] the language was limited to English for practical reasons.

2.2. Criteria for study selection

To address the objectives of the review, we conducted a systematic search of the literature based on the following criteria:

(i) Targeted population: ED patients aged over 16 years.
(ii) Environmental exposure: Patient overcrowding.
(iii) Outcomes: ED deaths (mortality occurring within EDs, including deaths due to delays in care, treatment complications, or critical conditions exacerbated by overcrowding), elopement (left against medical advice [LAMA] patients), leave LWBS, ICU admissions, or revisit rates (measured by the rate of return to ED), prolonged waiting time, patients left without complete assessment, prolonged length of stay (LOS), patients with pain suffering, patients' dissatisfaction, delayed treatment, delayed identification, delayed hospital admission, age group classifications, gender distribution analysis, and Emergency Severity Index (ESI) levels.

Studies were included if they met all of the following conditions:

(i) Study population: ED patients aged over 16 years.
(ii) Study type: Quantitative research designs, including both observational (cohort, case-control, and retrospective studies) and interventional studies (randomized controlled trials and non-randomized comparative trials). Exploratory studies and mixed-method research (qualitative and quantitative) were also included. Review articles were excluded, but their reference lists were screened to identify potentially eligible studies.
(iii) Focused on mortality caused by ED overcrowding, which were original research and published in peer-reviewed journals.
(iv) Only published full papers were included; abstracts were excluded.
(v) Published within the past 15 years (2010–2024).
(vi) Involved human patient populations.
(vii) Had no limitations on ethnicity or gender.
(viii) Written in English.

Any article that did not meet our inclusion criteria was eliminated:

(i) Studies that did not address the research question were excluded.
(ii) Animal data.
(iii) Studies related to catastrophes or major environmental events, such as typhoons, hurricanes, and earthquakes.
(iv) Case reports or studies with < 10 patients.
(v) Studies with incomplete data or duplication.
(vi) Systematic reviews and the pediatric population.
(i) Studies not yet published.
(ii) Papers not published in peer-reviewed journals.
(iii) Languages other than English.

2.3. Data extraction and management

Two researchers used the search approach to filter the titles and abstracts of the identified papers for inclusion. Any disagreements were resolved through consultation with a third investigator or by reaching a consensus. After abstract selection, a detailed review of the papers was carried out by four investigators. An organized table with detailed descriptions of the completed trials was used to retrieve data. In all identified articles, the following attributes were assessed:

(i) Reference details: authorship(s), published or unpublished, year of publication, study period, and other relevant cited papers.
(ii) Study characteristics: study design, topic, sample size, and region.
(iii) Population characteristics: number of participants, demographic data, and co-morbidities.
(iv) Main results: delay in management and its associated complications and mortality rate.

2.4. Risk of bias and applicability

The review writers worked in pairs to independently assess the likelihood of bias in the selected studies and the applicability of their findings using QUADAS-2.[9] Any inconsistencies were resolved through discussion and consultation with the principal author. Factors of research quality, such as participant spectrum, index tests, goal conditions, reference standards, flow, and scheduling, were addressed. A study was considered as having a high risk of bias if at least one of the QUADAS-2 domains was rated as high risk.

2.5. Statistical analysis

The statistical analysis of this study involved descriptive statistics, regression analysis, meta-analysis, and correlation testing to assess the impact of ED overcrowding on patient outcomes. Means, medians, standard deviations (SD), and proportions were used to summarize key variables, including waiting times, LOS, admission rates, and mortality rates. A random-effects meta-analysis model was applied to pool data from multiple studies, evaluating heterogeneity (I^2) and confidence intervals (CI), with forest plots used for visualization. Regression analysis assessed the association between overcrowding, LOS, mortality rates, and revisit rates (measured by the rate of return to ED), with *p*-values and hazard ratios measuring statistical significance.

3. Results

This review analyzed 11 studies published between 2010 and 2024 that focus on patient care outcomes in ED overcrowding, as illustrated in Figure 1.

As summarized in Table 1, the current study analyzed 3,084,344 patients, with a hospital admission rate of 14.7% and an equal gender distribution of 49% males and 51% females.

As presented in Table 2**,** patients admitted to EDs were most commonly within the middle age group of 21–40 years (43.4%), followed by 41–60 years (31.9%). The least representation was in the age groups < 20 years and > 60 years (12.8% and 11.9%, respectively).

As shown in Table 3, the minimum waiting time before the first examination was 30 min, and the maximum was 360.0 min (6 h), with a mean of 234.0 ± 21.7 min. The total LOS in the ED across the studied literature ranged from 123.5 to 540.0 min, with a mean of 245.8 ± 95.9 min.

As indicated in Table 4, ESI was classified into five levels, with Level 1 indicating the highest severity and Level 5 the lowest severity. The most common incidence was in Level 4, followed by Level 3, then Level 2, and the least was in Levels 1 and 5.

According to Table 5, most of the patients were home discharged (67.6%), and some were returned to ED (10.9%) in the studied literature due to unresolved or worsening conditions. On the other hand, 2.31% died, 1.88% eloped, 3.08% LWBS, and 1.26% had ICU admission.

As seen in Table 6, regression analysis of ED overcrowding in the age group lower than 60 years was significantly higher than that of elderly patients over 60 years ($p < 0.001$).

As depicted in Figure 2, pooling of studies using the random-effects method (REM) with 95% CI showed that there is a considerable heterogeneity ($I^2 = 93.9\%$) with statistically highly significant difference ($p < 0.001$) in longitudinal comparison between patients lower than 60 years than that of age group over 60 years.

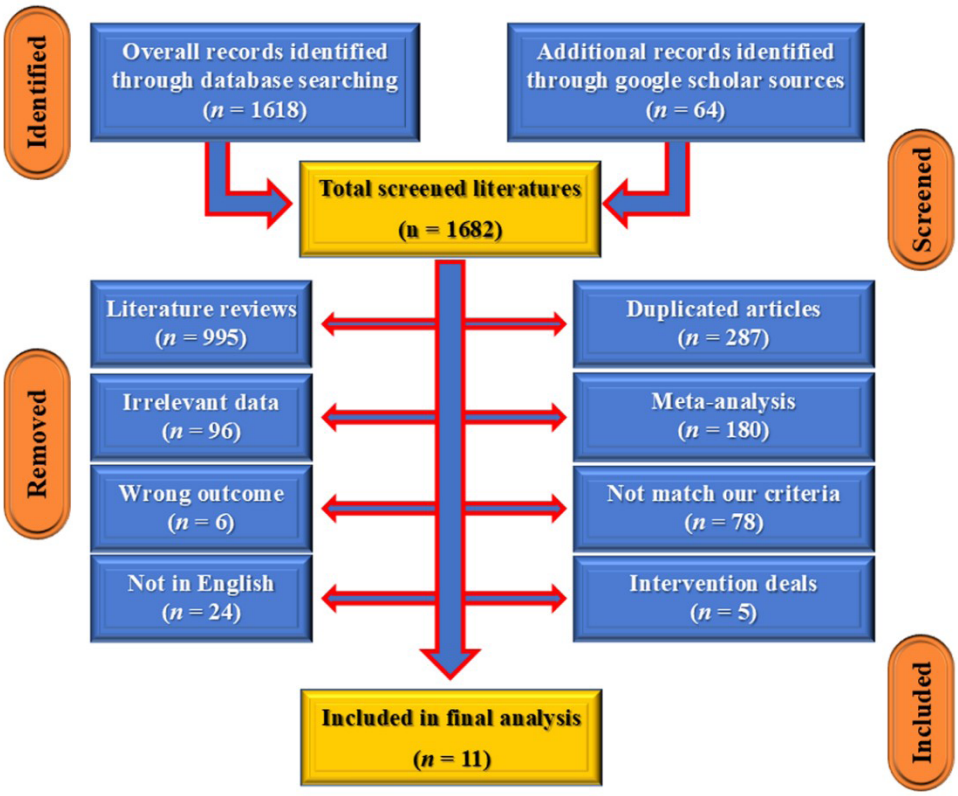

Figure 1. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) search strategy. The study selection process adhered to PRISMA guidelines, showing the number of studies identified, screened, included, and excluded.

Table 1. Summary of patient number, hospital admission rate, and gender distribution in the selected literature

Authors	Publication year	Studied patients	Admission (%)	Males (%)	Females (%)
de Araujo *et al.*[10]	2013	32,000	6.8	42.4	57.6
Chan *et al.*[11]	2017	208,585	8.2	55.9	44.9
Phillips *et al.*[12]	2017	2,557	10.6	42.0	58.0
Amodio *et al.*[13]	2018	416,299	2.6	37.3	62.7
Abir *et al.*[14]	2019	111,529	11.2	54.6	45.4
Doan *et al.*[15]	2019	1,931,465	20.0	-	-
Khubrani and Al-Qahtani[16]	2020	110,553	-	53.2	46.8
Jung *et al.*[17]	2021	73,776	23.7	46.2	53.8
Ouyang *et al.*[18]	2022	146,743	23.0	48.2	51.8
Getachew *et al.*[19]	2024	899	-	61.4	38.6
Marzano *et al.*[20]	2024	49,938	26.0	49.1	50.9
Total/mean ± SD		3,084,344	14.7 ± 7.5	49 ± 5.8	51 ± 5.7

Table 2. Age group distribution (pooled across 11 studies) and study-level summary statistics of mean age for patients admitted to emergency departments

Age group (years)	<20	21–40	41–60	>60	
Percent (%)	12.8	43.4	31.9	11.9	
	Min	**Max**	**Average**	**±SD**	**Median**
Mean age across studies (years)	3.9	68	35.9	11.3	37.3

Table 3. Emergency department (ED) waiting time and length of stay (LOS)

Waiting time (min)	Min	Max	Mean	±SD
Before examination	30.0	360.0	234.0	21.7
Total ED time (LOS)	123.5	540.0	245.8	95.9

Table 4. The triage of emergency severity index (ESI)

ESI level	Min (%)	Max (%)	Mean (%)	±SD (%)
1	0.5	39.1	10.3	14.4
2	7.7	70.3	26.4	18.4
3	15.8	61.2	31.8	12.6
4	8.4	54.6	34.1	17.9
5	0.8	23.9	9.91	7.3
Unclassified	0.1	1.2	0.78	0.46

Table 5. Patient outcomes in emergency department overcrowding

Outcome	Min (%)	Max (%)	Mean (%)	±SD (%)
Death	0.05	7.80	2.31	2.62
Eloped (escape)	0.30	3.45	1.88	1.58
LWBS	0.30	5.00	3.08	1.39
RTED	8.00	13.30	10.92	1.90
ICU admission	0.33	2.20	1.27	0.94
Discharged	39.40	80.30	67.63	13.70

Abbreviations: ICU: Intensive care unit; LWBS: Left without being seen; RTED: Returned to the emergency department.

Table 6. Meta-analysis of emergency department overcrowding and its relationship to age

Age	<60 years		≥60 years	
Events	69.3%		30.7%	
HR	4.599		0.568	
95% CI	LB	UB	LB	UB
Intercept	3.246	5.952	−0.723	1.858
Significance	r = 0.9251		$p < 0.001$	

Abbreviations: CI: Confidence interval; HR: Hazard ratio; LB: Lower bound; UB: Upper bound; r: Correlation coefficient.

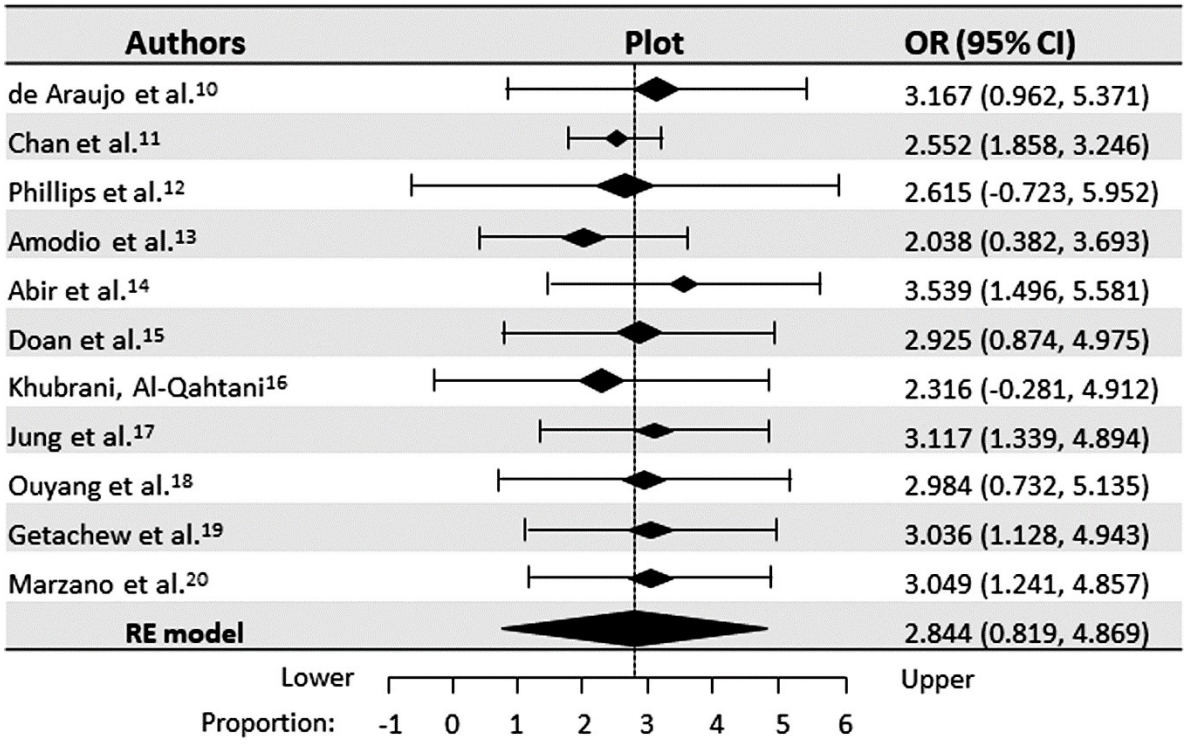

Figure 2. Forest plot showing the relationship between emergency department overcrowding and patients' age
Abbreviations: OR: Odds ratio; RE: Random effect.

As depicted in Figure 3, there is no evidence of publication bias with a symmetrical funnel plot. The rank correlation test and regression analysis for funnel plot asymmetry was statistically significant (r = 0.9251, p < 0.001) in patients with age group < 60 years than that over 60 years.

As reported in Table 7, regression analysis for ED overcrowding by gender in the studied literature showed a statistically non-significant difference between males and females (p > 0.05). Both genders showed symmetrical behavior.

As shown in Figure 4, the pooling of studies using REM with 95% CI showed that there is a mild heterogeneity (I^2 = 41.2%) with a statistically non-significant difference (p > 0.05) in longitudinal comparison between males and females.

Table 7. Meta-analysis of emergency department overcrowding and its relationship to gender

Gender	Males		Females	
Events	49%		51%	
HR	1.684		0.183	
95% CI	LB	UB	LB	UB
Intercept	0.723	2.645	−5.521	5.887
Significance	r = 0.0253		p > 0.05	

Abbreviations: CI: Confidence interval; HR: Hazard ratio; LB: Lower bound; UB: Upper bound; r: Correlation coefficient.

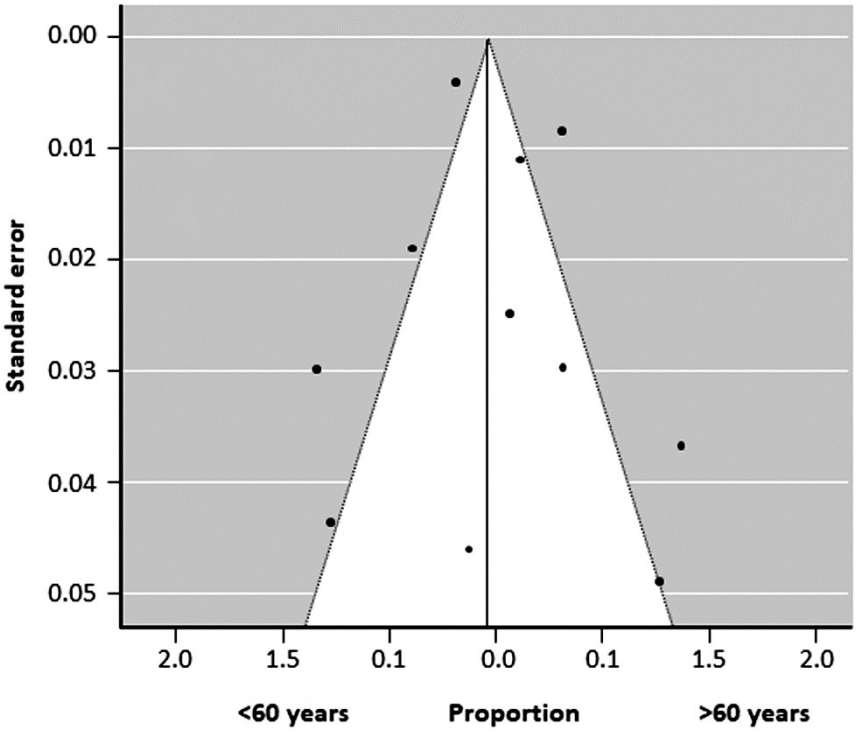

Figure 3. Funnel plot illustrating the relationship between emergency department overcrowding in two age groups

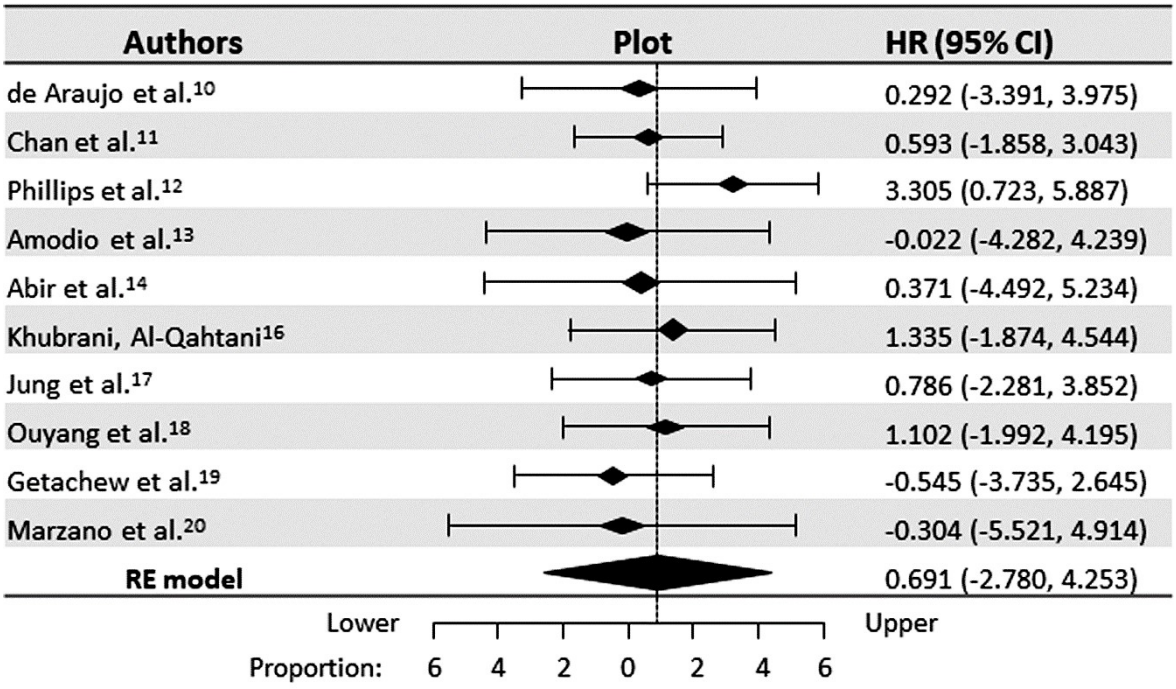

Figure 4. Forest plot showing the relationship between emergency department overcrowding and gender
Abbreviations: OR: Odds ratio; RE: Random effect.

As shown in Figure 5, there is no evidence of publication bias with a symmetrical funnel plot. The rank correlation test and regression analysis for funnel plot asymmetry were statistically nonsignificant (r = 0.0253, $p > 0.05$) between the two groups.

As detailed in Table 8, regression analysis of ED overcrowding in relation to waiting time in the studied literature showed a statistically significant correlation between waiting time and ED overcrowding ($p = 0.007$).

As illustrated in Figure 6, the pooling of studies using REM with 95% CI showed that there is considerable heterogeneity ($I^2 = 83.2\%$) with a statistically significant correlation between the two parameters.

As illustrated in Figure 7, there is no evidence of publication bias with a symmetrical funnel plot. The rank correlation test and regression analysis for funnel plot asymmetry were statistically significant (r = 0.6247, $p < 0.01$) between the two parameters.

As seen in Table 9, regression analysis for the effect of LOS on ED overcrowding in the studied literature showed a statistically significant increase in LOS during overcrowding ($p = 0.004$).

As shown in Figure 8, the pooling of studies using REM with 95% CI showed that there is a considerable heterogeneity ($I^2 = 94.5\%$) with a statistically highly significant difference ($p = 0.004$) in cases of ED overcrowding.

As shown in Figure 9, there is no evidence of publication bias with a symmetrical funnel plot. The rank correlation test and regression analysis for funnel plot asymmetry were statistically significant between the two parameters (r = 0.7668, $p < 0.01$).

4. Discussion

Emergency departments are crucial parts of healthcare systems, providing vital treatment to individuals in need of urgent medical attention. An increase in the number of individuals seeking care signals ED congestion, which leads to prolonged waiting times, delayed treatment, and reduced quality of care.[20]

The current systematic review and meta-analysis on the impact of ED overcrowding on patient outcomes provides significant insights into patient care, demographic patterns, and health outcomes associated with crowded emergency settings. The current study encompassed a large sample of 3,084,344 patients, with a nearly equal gender distribution of 49% male and 51% female.

The comprehensive examination of patient demographics provides critical insights into the population

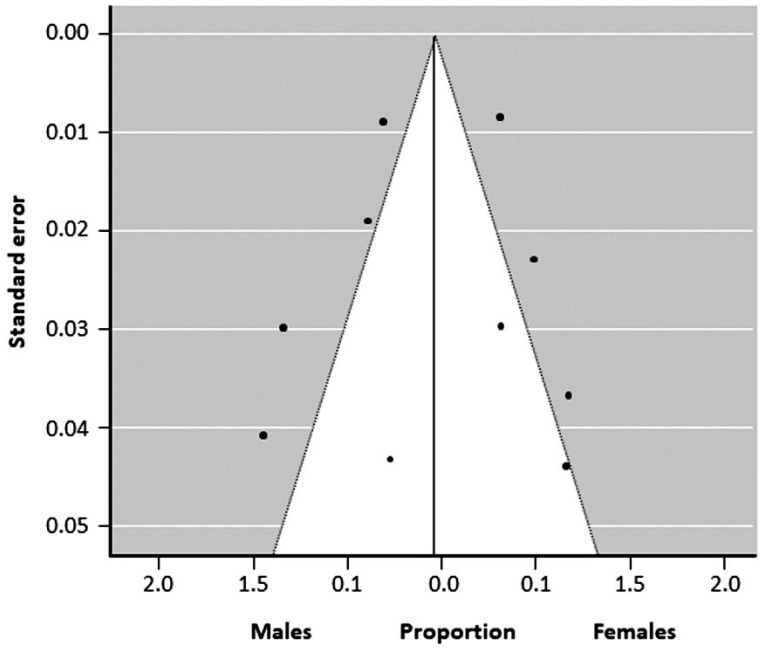

Figure 5. Funnel plot illustrating the relationship between emergency department overcrowding and gender

Table 8. Meta-analysis of emergency department (ED) overcrowding and its relationship to ED waiting time

	ED waiting time	
Mean ± SD (min)	46.87 ± 17.96	
HR	2.632	
95% CI	LB	UB
Intercept	0.752	4.512
Significance	r = 0.6247	p = 0.007

Abbreviations: CI: Confidence interval; HR: Hazard ratio; LB: Lower bound; UB: Upper bound; r: Correlation coefficient.

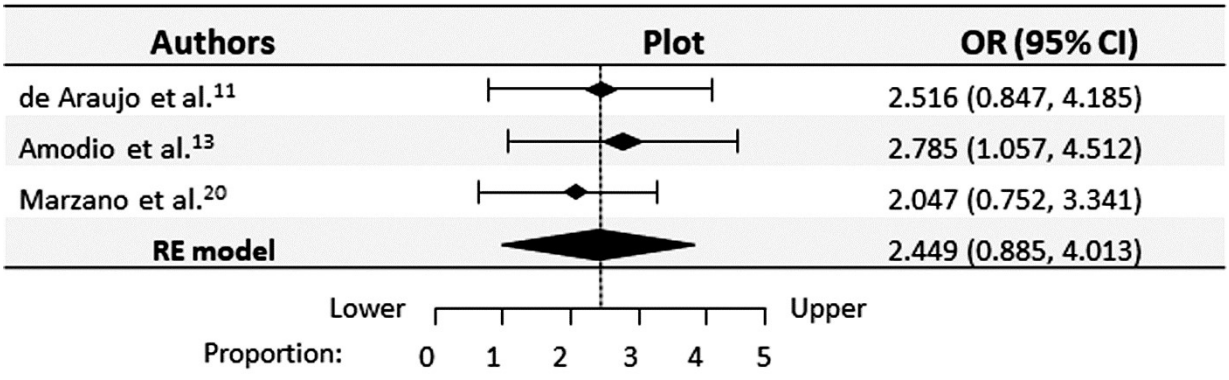

Figure 6. Forest plot showing the relationship between waiting time and emergency department overcrowding
Abbreviations: OR: Odds ratio; RE: Random effect.

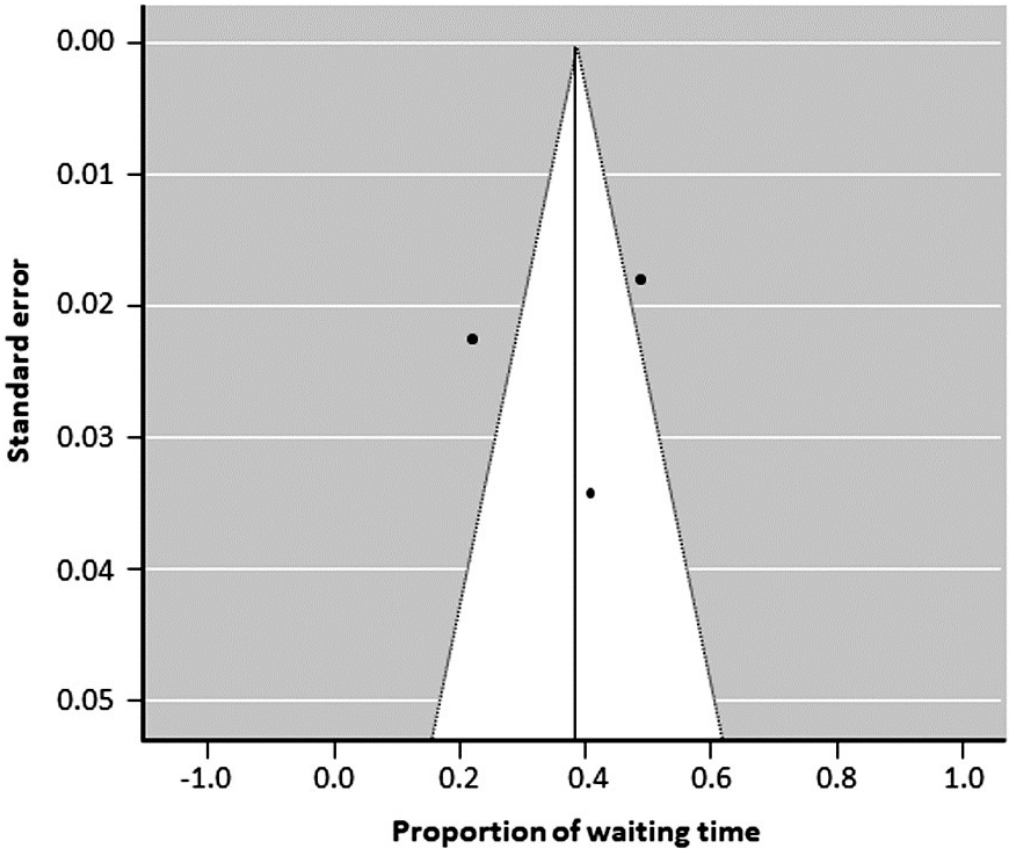

Figure 7. Funnel plot illustrating the relationship between waiting time and emergency department overcrowding

Table 9. Meta-analysis for emergency department (ED) overcrowding and its relationship to length of stay (LOS)

		LOS
Mean ± SD (min)		245.8 ± 95.9
HR		14.254
95% CI	LB	UB
Intercept	0.597	27.91
Significance	r = 0.7668	$p = 0.004$

Abbreviations: CI: Confidence interval; HR: Hazard ratio; LB: Lower bound; UB: Upper bound; r: Correlation coefficient.

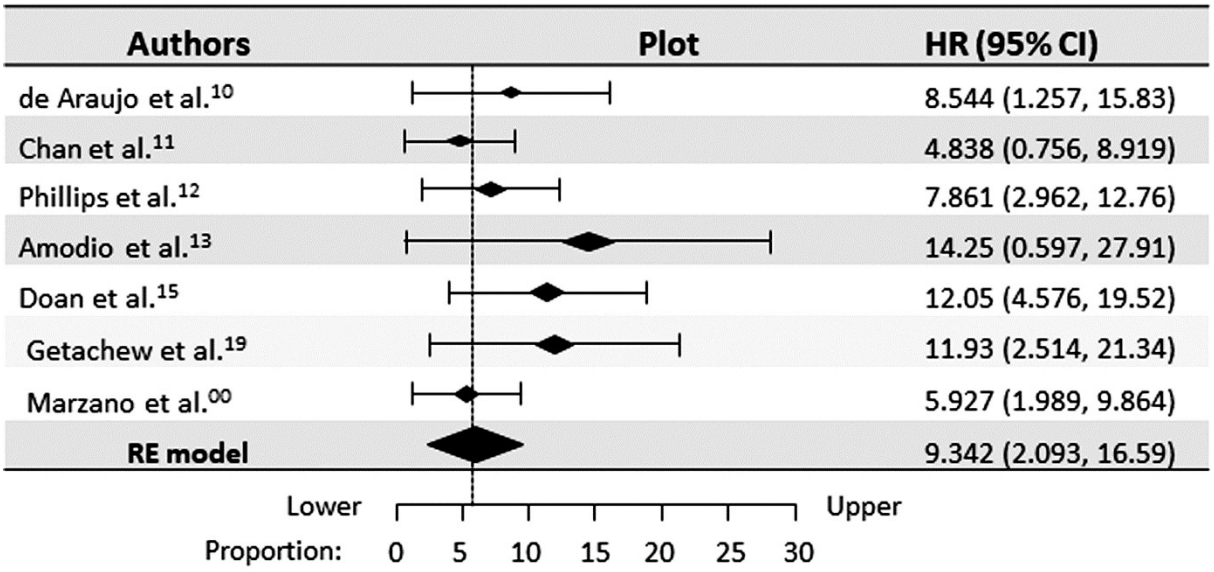

Figure 8. Forest plot showing the relationship between length of stay and emergency department

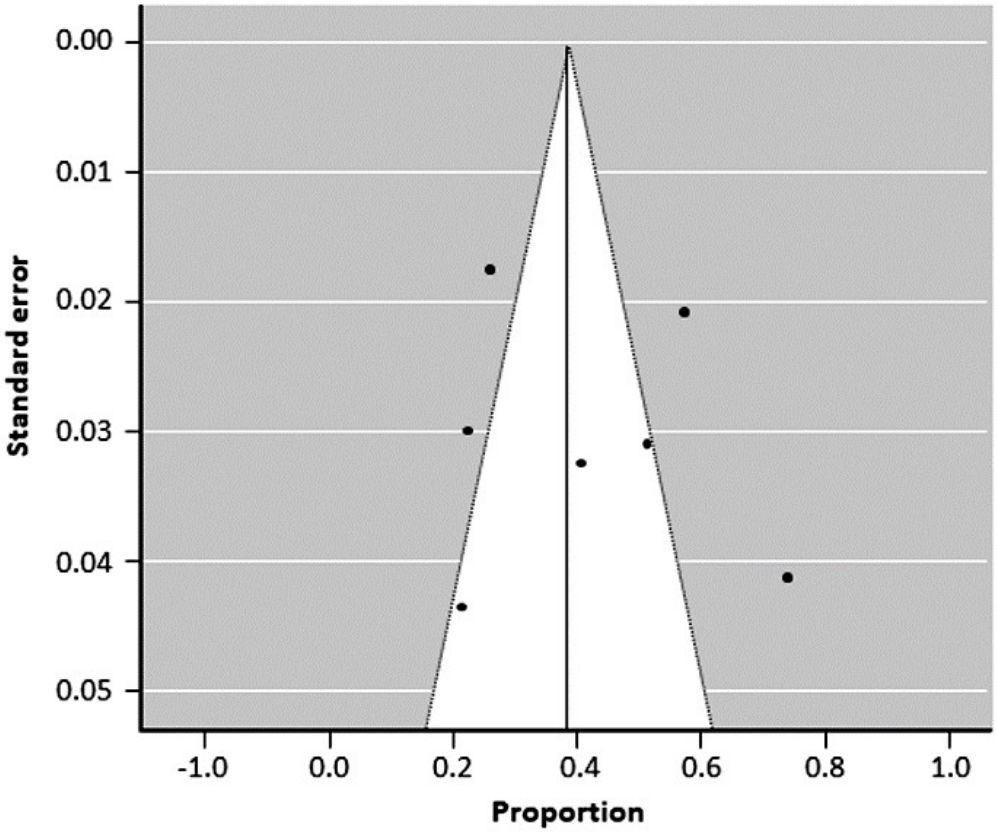

Figure 9. Funnel plot illustrating the relationship between emergency department overcrowding and length of stay

segments most impacted by ED overcrowding. Notably, patients aged 21–40 represented the largest group accessing ED services (43.4%), followed by those aged 41–60 (31.9%). This suggests that younger adults and middle-aged individuals are more likely to seek emergency care, potentially due to the high rate of accidents, injuries, and acute medical needs within these age groups. Importantly, the analysis revealed a statistically significant impact of ED overcrowding on patients under 60 compared to older adults ($p < 0.001$), with a correlation coefficient of r = 0.9251. This disparity underscores that younger patients may face greater delays or adverse effects due to ED overcrowding, potentially due to differing medical triage priorities or the immediate care needs of older patients, which are often prioritized. Such findings highlight the need for tailored strategies to address the varying impacts of overcrowding on different age demographics.

Waiting times and LOS emerged as critical indicators in the analysis, reflecting the direct impact of overcrowding on patient experience and care quality. The results revealed that ED overcrowding substantially increased both waiting times and the overall LOS. The mean waiting time before the initial examination was reported as 234 min, with a range extending up to 360 min in some cases. This delay in assessment can contribute to patient dissatisfaction, symptom exacerbation, and a higher likelihood of adverse outcomes. Phillips *et al.*[12] and Marzano *et al.*[20] noted that waiting times extended across all triage levels during periods of peak overcrowding. Notably, de Araujo *et al.*[10] highlighted that those patients without insurance or those on Medicaid experienced disproportionately longer waiting times compared to privately insured patients, amplifying their likelihood of adverse outcomes. Similarly, Amodio *et al.*[13] observed statistically significant increases in waiting times, particularly during the winter months when EDs experienced their highest volumes, with an additional 7–9 min added per patient for lower triage codes.

Furthermore, the mean LOS was calculated at 245.8 min, with significant variance (±95.9 min), underscoring the prolonged time patients spend in EDs due to overcrowding. Regression analysis showed a strong correlation between increased LOS and overcrowding ($p = 0.004$, r = 0.7668), highlighting how congestion in EDs significantly extends both patient waiting and treatment times. These findings suggest that addressing bottlenecks in the ED process could reduce waiting times and LOS, thereby enhancing patient outcomes and satisfaction.

Several studies identified systemic contributors to prolonged LOS, including bottlenecks in hospital bed availability and inefficiencies in triage or discharge processes. Marzano *et al.*[20] and Ouyang *et al.*[18] reported that imaging requests and bed shortages were major contributors to prolonged LOS, particularly for patients requiring diagnostics such as computed tomography scans, where LOS extended to an average of 6.51 ± 4.81 h. These studies also highlighted that LOS was not significantly influenced by patient acuity; even high-acuity cases experienced delays when EDs were saturated. Similarly, Jung *et al.*[17] noted that patients with lower triage levels often had extended LOS because of resource reallocation to higher-acuity cases. Furthermore, Phillips *et al.*[12] found that LOS increased disproportionately during "extremely busy" or "overcrowded" periods, with mean LOS exceeding the standard median of 150 min in median-volume EDs.

Patient demographics and conditions also influenced LOS and waiting times. Chan *et al.*[11] observed that pediatric patients with noncritical conditions experienced relatively shorter LOS compared to adults. However, their outcomes were still adversely affected by overcrowding. In contrast, Amodio *et al.*[13] found that older adults and individuals with chronic conditions were disproportionately affected by delays, with LOS significantly exceeding the average.

Prolonged waiting times and LOS had cascading effects on patient outcomes. Abir *et al.*[14] reported that high LOS periods correlated with increased rates of adverse events, such as revisits and incomplete assessments. Cumulative delays in treatment initiation were associated with higher dissatisfaction rates and, in some cases, increased mortality risks[10]. Importantly, Doan *et al.*[15] observed that even pediatric patients experienced delays in care delivery and subsequent admissions.

Our analysis categorized patients across various levels of the ESI, revealing that most patients were categorized within ESI levels 3 and 4. These levels generally indicate a moderate to less urgent condition, where immediate life-threatening risks are absent, but timely intervention is required. The prevalence of ESI levels 3 and 4 patients reflects the challenge EDs face in balancing resources between critically urgent cases (ESI levels 1 and 2) and those that, while not immediately life-threatening, require prompt care. This distribution suggests that EDs are managing a significant volume of cases that, while urgent, may not be life-threatening, adding to the overcrowding strain. Addressing this issue could involve implementing strategies to divert lower-acuity cases to alternative care facilities or urgent care centers. This would partially alleviate the burden on EDs.

Across the studies, the distribution of cases revealed a predominance of moderate-severity patients (ESI level 3) and lower-severity cases (ESI levels 4 and 5). For instance, Marzano *et al.*[20] reported that over 39% of patients in overcrowded EDs were assigned lower acuity triage codes

(yellow and green codes), often associated with non-urgent or generic symptoms. Similarly, Amodio *et al.*[13] highlighted an increase in critical and semi-critical cases (red and yellow codes) during peak overcrowding periods alongside a rise in lower-severity admissions. Lower-severity patients, particularly those assigned ESI levels 4 and 5, were disproportionately affected during periods of overcrowding. Jung *et al.*[17] and Abir *et al.*[14] found that as ED occupancy rose, the admission rates for ESI levels 4 and 5 patients increased significantly, potentially due to the prolonged waiting times and the inability to discharge or redirect non-urgent cases efficiently. Additionally, Khubrani *et al.*[16] noted that overcrowded conditions led to a higher proportion of lower-acuity patients utilizing ED services, often straining limited resources that were needed for higher-severity cases.

Although lower-severity cases were more directly impacted in terms of delays, high-severity cases (ESI levels 1 and 2) also faced challenges due to overcrowding. Ouyang *et al.*[18] demonstrated that ED census and physician workload census negatively affected the efficiency of care for high-acuity cases, leading to delayed critical interventions. This finding was echoed by Amodio *et al.*,[13] who reported that even critical cases experienced marginally increased waiting times and LOS during overcrowding, highlighting the systemic nature of the problem. Furthermore, previous studies utilized various triage systems, including ESI, Korean Triage and Acuity Scale (KTAS), and National Emergency Department Overcrowding Score (NEDOCS), to evaluate the severity of ED overcrowding and its impacts. Jung *et al.*[17] found that patients with lower KTAS levels (3–5) experienced greater increases in admission rates as overcrowding intensified. Similarly, Phillips *et al.*[12] reported comparable trends using the NEDOCS for severity evaluation. Despite these variations, the overarching conclusion across studies remained consistent: while lower-acuity cases disproportionately absorbed the impact of overcrowding, higher-acuity cases were not immune to its ripple effects.

In our meta-analysis, patient outcomes during overcrowding were characterized by prolonged waiting times, delays in care delivery, and suboptimal medical decisions. The results revealed that 67.6% of patients were discharged home, while 10.9% revisited the ED within days, indicating potential inadequacies in initial assessments or discharge planning due to time pressures and overcrowding. Additionally, 2.31% of patients died while in the ED, and a similar percentage of patients either LWBS or eloped. Notably, mortality rates ranged from 0.05% to 7.8%, depending on the study and context. Khubrani *et al.*[16] observed that mortality was not directly correlated with overcrowding but identified higher mortality rates in specific subgroups, such as middle-aged patients, during overcrowded periods. Similarly, Amodio *et al.*[13] reported a marginal increase in deaths during overcrowding, with critical patients disproportionately affected.

Our meta-analysis revealed that adverse events commonly associated with ED overcrowding included increased rates of LWBS and revisits, delayed diagnoses, and incomplete assessments. Chan *et al.*[11] found a strong association between overcrowding and LWBS rates, which in turn correlated with elevated pediatric intensive care unit admission rates. For pediatric populations, Doan *et al.*[15] highlighted that overcrowding increased hospital revisits, particularly for low-acuity cases, as delayed care compounded the risk of subsequent complications.

Overcrowding also significantly influenced revisit and admission patterns. Ouyang *et al.* [14] found a positive association between boarder census levels and 7-day revisit probabilities, reflecting unsafe discharge practices. Similarly, Abir *et al.*[14] reported that overcrowding reduced the odds of immediate hospitalization while increasing revisit rates, especially during high-occupancy periods.

Another significant adverse event was the increased likelihood of elopement or LAMA patients. Amodio *et al.*[13] noted that 4.46% of patients left the ED during overcrowded periods, up from 4.15% during less busy times. These trends reflect patient frustration and dissatisfaction stemming from prolonged waits and inadequate communication.

Vulnerable populations, such as pediatric and elderly patients, were disproportionately affected. Doan *et al.*[18] found that pediatric patients, particularly those with low-acuity triage levels, faced higher risks of revisits and delayed care, which could escalate into more severe conditions. For elderly patients, Amodio *et al.*[13] and Marzano *et al.*[20] identified prolonged LOS and delayed admissions, often exacerbated by comorbidities and the complexity of care coordination. These statistics underscore the risks posed by overcrowding, as patients may not receive adequate or timely care, potentially exacerbating their conditions. The significant correlation between these outcomes and overcrowding indicates a clear need for improvements in ED protocols and resource allocation to minimize adverse events.

The current study further examined the impact of overcrowding on healthcare workers, identifying increased medical errors, burnout, and psychological stress as prevalent issues. When EDs are overcrowded, healthcare providers are often under intense pressure, which can impair decision-making and lead to mistakes. Studies such as those from Sayah *et al.*[21] and Amorim *et al.*[22]

documented the psychological toll of overcrowding on healthcare workers, including stress, burnout, and work-related anxiety. These conditions were linked to increased absenteeism, reduced job satisfaction, and diminished overall well-being among staff. Prolonged exposure to overcrowded conditions led to a decrease in performance, undermining the efficiency and effectiveness of healthcare delivery. Stress levels were particularly elevated during periods of extreme overcrowding, as described by Phillips *et al.*,[12] where staff struggled to balance patient care demands with limited time and resources.

Overcrowding significantly increased the risk of medical errors, as noted in studies like Wang *et al.*[23] Errors arose from the rushed decision-making necessitated by high patient volumes and fragmented care pathways. Delays in communication between team members and the prioritization of critical patients often resulted in suboptimal outcomes for lower-acuity cases. Martin *et al.*[24] found that overcrowding decreased the speed of service delivery and the overall quality of care provided to patients. Furthermore, reduced focus on detailed documentation and assessments during peak times was identified as a contributing factor to diagnostic inaccuracies.

Healthcare workers' inability to deliver timely and comprehensive care during overcrowded periods negatively affected patient satisfaction. Marzano *et al.*[20] highlighted that prolonged waiting times and limited patient-healthcare provider interactions led to dissatisfaction, with many patients LWBS or LAMA. The studies emphasized that the cumulative effect of staff fatigue, resource scarcity, and systemic inefficiencies diminished care quality, with adverse consequences for both patient safety and clinical outcomes. Therefore, interventions aimed at alleviating overcrowding must also address support systems for healthcare workers. This includes making staffing adjustments, ensuring adequate rest periods, and implementing stress management programs, all of which are essential for maintaining a high standard of patient care.

Gender-based analysis showed no statistical significance between the effects of ED overcrowding on male and female patients ($p > 0.05$). This suggests that overcrowding impacts both genders similarly, aligning with the broader observation that ED congestion affects all patient demographics. The non-significant gender differences indicate that interventions aimed at reducing ED overcrowding can be universally applied without the need for gender-specific adjustments. Across the studies, the patient population was nearly equally split, with 49% male and 51% female. Amodio *et al.*[13] and Khubrani *et al.*[16] found no significant gender differences in mortality rates or adverse outcomes, suggesting that overcrowding exerted a universal burden regardless of gender. However, slight variations in certain studies hinted at gender-specific vulnerabilities. For instance, males were observed to have higher mortality rates in some scenarios, although these findings were not consistent across all studies.

Among pediatric patients, Chan *et al.*[11] reported that boys often presented with higher acuity levels compared to girls, potentially affecting their outcomes during overcrowded periods. In elderly populations, Marzano *et al.*[20] noted that male patients frequently required more resource-intensive interventions, such as imaging or critical care admissions, which could be delayed due to overcrowding. In contrast, female patients were more likely to report dissatisfaction with the waiting experience and perceived delays in treatment. Ouyang *et al.*[18] observed a slight increase in revisit rates among males compared to females, particularly for non-urgent cases. This was attributed to differences in healthcare-seeking behavior, where male patients were less likely to seek follow-up care proactively, leading to recurrent visits for unresolved issues.

5. Strengths of the study

This meta-analysis leverages data from 11 comprehensive studies spanning over a decade (2010–2024), encompassing diverse healthcare settings, populations, and methodologies. The large sample size of over 3 million patients in the current review enhances the robustness of the findings, allowing for generalizability across different regions and ED environments. The inclusion of multiple triage systems, such as ESI, NEDOCS, and KTAS, provides a nuanced understanding of how triage severity interacts with overcrowding. Furthermore, the current analysis captures a wide range of outcomes, including waiting times, LOS, adverse events, patient satisfaction, and healthcare worker well-being, offering a holistic view of the impact of overcrowding. Advanced statistical methods, including regression analyses and hazard ratios, strengthen the reliability of results and underscore significant patterns, such as the association between ED overcrowding and adverse outcomes.

6. Limitations of the study

Despite its strengths, the analysis is not without limitations. The heterogeneity in study designs, populations, and metrics used to define overcrowding poses challenges for direct comparison and synthesis. Variability in triage systems and operational workflows across regions may limit the applicability of findings to settings with differing healthcare infrastructures. Additionally, some studies

lack granular data on subpopulations, such as uninsured patients or those with chronic conditions, which may obscure specific vulnerabilities. Publication bias is another concern, as studies with negative or insignificant results may be underrepresented. Finally, the observational nature of many included studies precludes definitive causal inferences, leaving room for unmeasured confounders influencing the reported outcomes.

7. Conclusion

The current study found that ED overcrowding significantly impacted patient care outcomes, with a mortality rate of 2.31%. This aligns with general ED mortality rates (0.5–3%) and highlights how delayed care and prolonged LOS exacerbate patient risks. Additionally, 10.9% of discharged patients returned to EDs, suggesting that overcrowding may lead to premature or inadequate treatment decisions. The average waiting time before the first examination was 234 ± 21.7 min, with some patients waiting up to 6 h, while the total ED LOS averaged 245.8 ± 95.9 min. A significant correlation (p = 0.007) was found between overcrowding and extended LOS, confirming that congestion disrupts patient flow and timely treatment. In terms of patient outcomes, 67.6% were discharged home, but 3.08% LWBS and 1.88% eloped (LAMA), underscoring concerns about access to care. The study reinforces that overcrowding leads to delayed treatment, increased mortality, and higher revisit rates, creating a cycle of inefficiency that strains both patients and healthcare providers.

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Conflict of interest

The authors have no conflicts of interest to declare.

Author contributions

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Writing – review & editing: All authors

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Not applicable.

Consent for publication

Not applicable.

Availability of data

The data used in the study can be obtained and is available upon reasonable request from the corresponding author.

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