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Effect of access block on emergency department crowding calculated by NEDOCS score

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ABSTRACT

Objective: Emergency department (ED) crowding poses a significant challenge in healthcare systems globally, leading to delays in patient care and threatening public health and staff well-being. Access block, characterized by delays in admitting patients awaiting hospitalization, is a primary contributor to ED overcrowding. To address this issue, the National Emergency Department Overcrowding Study (NEDOCS) score provides an objective framework for assessing ED crowding severity. This study aims to evaluate the impact of access block on ED crowding using the NEDOCS score and to explore strategies for mitigating overcrowding through scenarios over a 39-day period.

Methods: A single-center, prospective, observational study was conducted in an urban tertiary care referral center. The NEDOCS score was collected six times daily, including variables like total ED patients, ventilated patients, boarding patients, the longest waiting times, and durations of boarding patients. NEDOCS scores were recorded, and calculations were performed to assess the potential impact of eliminating access block in scenarios.

Results: NEDOCS scores ranged from 62.4 to 315, with a mean of 146, indicating consistent overcrowding. Analysis categorized ED conditions into different levels, revealing that over 81.2% of the time, the ED was at least overcrowded. The longest boarding patient's waiting duration was identified as the primary contributor to NEDOCS (48.8%). Scenarios demonstrated a significant decrease in NEDOCS when access block was eliminated through timely admissions. Shorter boarding times during non-working hours suggest the potential mitigating effect of external factors on the access barrier. Additionally, daytime measurements were associated with lower patient admissions and shorter wait times for initial assessment.

Conclusion: Although ED crowding is a multifactorial problem, our study has shown that access block contribute significantly to this problem. The study emphasizes that eliminating access block through timely admissions could substantially alleviate crowding, highlighting the importance of addressing this issue to enhance ED efficiency and overall healthcare delivery.

1. Introduction

Emergency department (ED) crowding represents a critical challenge in healthcare systems worldwide, particularly in densely populated regions [1]. This phenomenon not only leads to delays in patient evaluations and necessary treatments but also poses significant threats to public health, patient outcomes, and staff well-being [2,3]. The repercussions of ED overcrowding extend beyond mere inconveniences, potentially escalating to verbal, physical, or psychological violence. Addressing this issue is paramount to ensure efficient emergency care delivery and maintain patient and staff well-being [2-7].

The concept of ED overcrowding arises when the demand for emergency services surpasses the available capacity, resulting in a disruption of the supply-demand equilibrium within the ED. While various factors contribute to this imbalance, access block – the delay in admitting patients awaiting hospitalization – is consistently identified as a primary cause [3,8]. Access block not only hampers patient flow but also strains resources and exacerbates the overcrowding crisis [3,9].

To address the challenge of subjective assessments of ED crowding, Weiss et al. introduced the National Emergency Department Overcrowding Study (NEDOCS) score in 2004 [10]. This objective scoring system was designed to provide a standardized framework for assessing the severity of ED crowding across different institutions. By

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incorporating multiple parameters related to ED patient management, the NEDOCS score offers a reliable and reproducible measure of crowding levels, facilitating targeted interventions and resource allocation. Many studies in different countries have shown that the NEDOCS score successfully reflects ED crowding [11-13].

In light of the importance of access prevention in ED overcrowding, this study aims to evaluate its impact using the NEDOCS score with an understanding of the ED's dynamism. In this context, this study evaluates strategies to alleviate the difficulties caused by ED crowding through scenarios by eliminating the access block. These practices will enable resource utilization to be optimized, patient outcomes to be improved, and challenges to be alleviated.

2. Materials and methods

2.1. Study design

This single-center, prospective, observational, descriptive study was conducted at the Adult Emergency Department of Marmara University Pendik Training and Research Hospital. The hospital is an urban, medical school-affiliated tertiary care referral center with over 200,000 adult ED presentations annually. The hospital has 68 ED beds and 725 total beds. The study protocol approved by university's Institutional Review Board (IRB) (IRB No 09.2021.500).

2.2. Study setting and protocol

The NEDOCS score was employed to measure ED crowding during all shifts across 36 days within a 39-day span, from April 23, 2021, to June 1, 2021. Variables comprising the NEDOCS score were recorded six times daily during specified timeframes (09:00–10:00, 12:00–13:00, 16:00–17:00, 20:00–21:00, 24:00–01:00, 03:00–04:00), with three recordings during working hours and three during non-working hours. However, due to the unavailability of researchers, data collection was not conducted from 09:00–10:00 on May 6 to 03:00–04:00 on May 7, from 09:00–10:00 on May 13 to 03:00–04:00 on May 14, and from 09:00–10:00 on May 24 to 03:00–04:00 on May 25. Over the 36 days of data collection, accounting for a total loss of 3 days, 216 data points were gathered from six daily measurements. The data collection process ended when the targeted sample size was reached.

2.3. Variables and data measurement

2.3.1. Boarding patients definition

Boarding patients are individuals who have been evaluated in the ED, determined to require hospitalization, and have been formally admitted but remain in the ED due to a lack of available inpatient beds. During this time, they continue to receive necessary medical treatment in the ED until a suitable inpatient bed becomes available.

The variables used in the calculation of NEDOCS score include the total number of ED beds (A = 68), the total number of hospital beds (B = 725), the total number of patients in the ED (C), the number of ventilated patients in the ED (D), the longest boarding patient's waiting period (E), the number of boarding patients in the ED (F), and the longest waiting time for examination (G). The NEDOCS score is derived using the formula: 85.8(C/A) + 600(F/B) + 13.4(D) + 0.93(E) + 5.64 (G) – 20.

Table 1
NEDOCS Score Categorization [10].

Level	Score	Comment
Level 1	1–20	Not busy
Level 2	21–60	Busy
Level 3	61–100	Quite busy but not crowded
Level 4	101–140	Overcrowded
Level 5	141–180	Severely overcrowded
Level 6	181 +	Dangerously overcrowded, disaster

NEDOCS, National Emergency Department Overcrowding Scale.

Based on this score, ED crowding is categorized into six levels, as illustrated in Table 1 [10].

2.4. Working vs. non-working hours

Regular working hours refer to the period from 8:00 to 17:00, Monday through Friday. Non-working hours encompass the time from 17:00 to 08:00 on weekdays, as well as all hours during weekends and public holidays.

2.4.1. Day vs. Night

Measurements at 09:00–10:00, 12:00–13:00, and 16:00–17:00 are classified as daytime, whereas those at 20:00–21:00, 24:00–01:00, and 03:00–04:00 are deemed nighttime.

2.5. Scenarios

Turkish National Ministry of Health recommends that patient follow-ups in the ED should not exceed 24 h. In the later update, it was recommended that this period not exceed 8 h [14]. Similarly, in Australia, 8-h duration is used as an indicator of emergency department performance [15]. In South Korea, the 24-h Emergency Department Restriction Act was implemented in 2017 to reduce waiting times in the ED and aims to keep ED stays below 24 h [16]. Therefore, three scenarios created to examine the effect of admission of patients who need hospitalization in the ED immediately, in the 8th and 24th hours, via the NEDOCS score to ED crowding.

The number of boarding patients waiting for admission for over 8 h and over 24 h was recorded at each data point. The anticipated NEDOCS score was computed for each data point if these boarding patients were admitted immediately, at the 8th and 24th hours of their ED presentation. According to these scenarios, the new NEDOCS scores and the contributions of the parameters of this score were examined.

2.6. Study size

We estimated the minimum number of data points required to detect an effect size of 0.5 for comparing the mean NEDOCS scores between two data points. Our calculations indicated that at least 210 data points were necessary to achieve a Type I error rate of 5% and a power of 95%. To account for potential data loss, we increased this number by 10%, resulting in 231 data points. We then rounded up to match a discrete number of days, leading to a final total of 236 data points, which corresponds to 39 days.

$$\begin{aligned} \textit{NEDOCS Score} = {} & 85.8 \times \left(\frac{\text{total number of patients in the ED}}{\text{total number of ED bed}}\right) + 600 \times \left(\frac{\text{the number of boarding patients in the ED}}{\text{total number of hospital beds}}\right) + 13.4 \\ & \times (\text{number of ventilated patients in the ED}) + 0.93 \times (\text{the longest time in the ED for boarding patients since registration}) \\ & + 5.64 \times (\text{the longest waiting time for examination}) - 20 \end{aligned}$$

2.7. Statistical analysis

The analysis was conducted using the Statistical Package for Social Sciences (SPSS) 23.0 for Windows. To assess the normality of data distribution, the Kolmogorov-Smirnov test was used. Categorical variables are expressed as counts and percentages, while numerical variables are presented as medians with interquartile ranges. The continuous independent variables were analyzed using the Mann–Whitney *U* test. Statistical significance was defined as $p < 0.05$.

3. Results

During the year of the study, 172,891 patients were examined in Marmara University Pendik Training and Research hospital emergency departments. Of these patients, 11.9% ($n = 20{,}658$) were hospitalized. Of the hospitalized patients, 21.6% ($n = 4466$) were admitted to the ICU, and the rest were admitted to the ward.

The NEDOCS score and category were determined for 216 data points across 36 days and 72 shifts. The recorded NEDOCS scores ranged from 62.35 (quite busy but not crowded) to 314.56 (dangerously crowded), with a median score of 146.47 (severely overcrowded).

For 81.2% ($n = 176$) of the time, the ED was categorized as at least overcrowded (Level ≥ 4) according to the NEDOCS score. The NEDOCS score was Level III at 18.8% of the time, Level IV at 34.9% of the time, Level V at 25.2% of the time and Level VI at 21.1% of the time. Levels I and II were not observed during the study. The distribution of the NEDOCS score and ED crowding category during the study period is illustrated chronologically in Fig. 1.

The parameter contributing most to the total NEDOCS score on average was the longest boarding patient's waiting period (h) (47.5%), while the least contributing parameter was the number of intubated patients (3.8%) (Table 2). The effect of the number of admitted patients, the longest waiting time of the admitted patient, and the total number of patients in the ED on the total NEDOCS score are shown in Fig. 2.

Three scenarios were analyzed to assess the impact of boarding on ED crowding (Table 2). In the first scenario, if all boarding patients were admitted immediately, the mean NEDOCS score would decrease from 146.47 to 22.4 (an 84,7% decrease), bringing the average NEDOCS score level down to 2 (busy). In the second scenario, if all boarding patients were admitted within 8 h, the mean NEDOCS score would decrease to 24.7 (an 83.1% decrease). ED crowding categorization would reach Level I (not busy) in 89 data points (41.2%), Level II (busy) in 123 data points (56.9%) and Level III (quite busy but not crowded) in only 4 data points (1.8%), with no observations of Level IV, V, and VI crowding in first and second scenarios. Here, the "total number of patients" would become the primary parameter contributing to the NEDOCS score and ED crowding (45.6% of the total NEDOCS). In the third scenario, if all boarding patients were admitted within 24 h, the mean NEDOCS score would halved to 65.7. ED crowding would be at Level II (busy) in 91 data points (42.1%), Level III (quite busy but not crowded) in 111 data points (51.4%) and Level IV (overcrowded) in only 14 data points, with no occurrences of Level I, V, and VI crowding. In this case, the total number of patients would account for 43.4%, the number of boarding patients for 13.2%, and the most prolonged boarding patient's waiting period for 26.1% of the total NEDOCS score. The calculated NEDOCS score and the NEDOCS scores of the scenarios are compared in Fig. 3.

Regarding secondary outcomes, the mean waiting period of the longest-boarded patient was statistically significantly lower during non-working hours (75 vs 82; $p = 0.031$). The total number of patients presenting to the ED was significantly lower during daytime measurements (39 vs. 43.5; $p = 0.037$). Additionally, the mean waiting time for the initial physical examination was also shorter during the daytime (61.5 vs 81.5 min; $p < 0.001$). No significant difference was observed in other variables.

4. Discussion

In this single-center, prospective observational descriptive study, we aimed to evaluate the effects of access block on ED crowding using the NEDOCS score. Our results revealed that access block is a significant contributor to ED crowding, aligning with existing literature that highlights the importance of efficient patient flow and resource management in alleviating ED crowding.

Addressing access block issues can improve patient care quality, reduce waiting times, and enhance satisfaction among patients and staff within the emergency setting. Several studies have documented the association between access block and ED crowding. For instance, Hoot and Aronsky conducted a systematic review demonstrating a strong relationship between access block and ED crowding, suggesting that

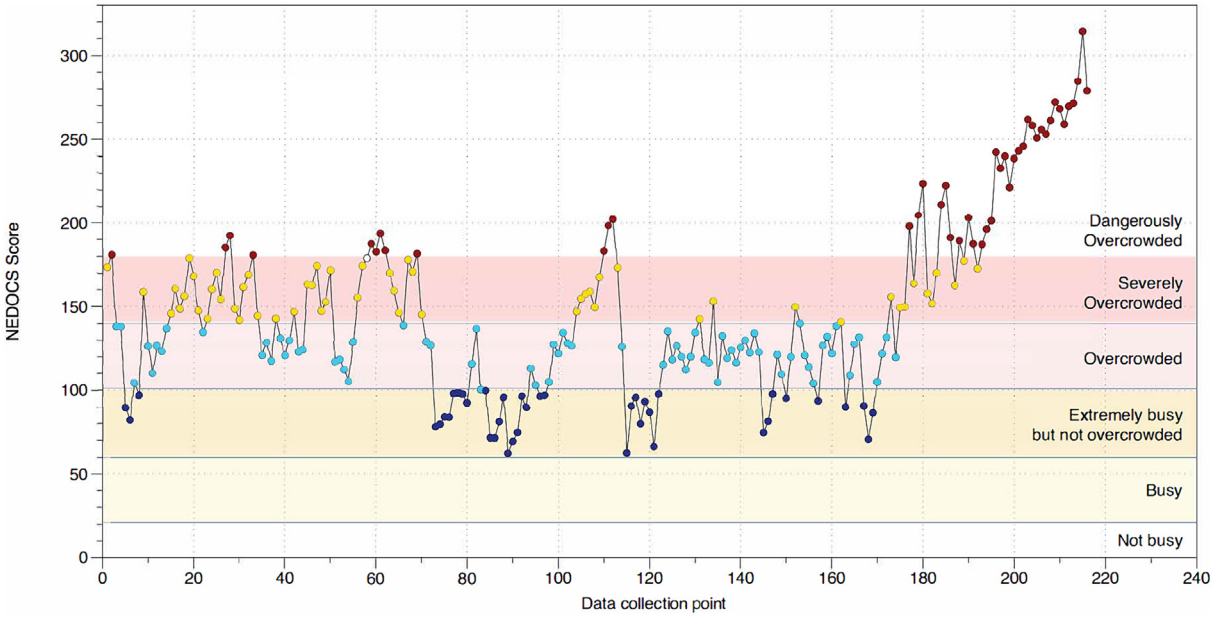

Fig. 1. The distribution of the NEDOCS score and ED crowding category during the study period.

Table 2
Observed and simulated NEDOCS scores if boarding patients were transferred to a ward/ICU bed as soon as they were ordered for admission after eight and 24-h waiting.

	Observed NEDOCS Score		Scenarios NEDOCS Score					
	Observed Score		Scenario 1*		Scenario 2*		Scenario 3*	
	Median (IQR)	Contribution on NEDOCS Score (% of total)	Median (IQR)	Effect on NEDOCS Score (% of total)	Median (IQR)	Contribution on NEDOCS Score (% of total)	Median (IQR)	Contribution on NEDOCS Score (% of total)
Number of total patients	41.0 (35.0–46.0)	50.6 (31.7)	16 (12−20)	20.3 (47.9)	16 (12–20)	20.3 (45.7)	29 (25–34)	36.8 (43.3)
Number of boarding patients	23.5 (18.0–29.0)	19.9 (12)	0 (0–0)	0 (0.0)	2 (0–4)	2.0 (4.5)	13 (10–17)	11.3 (13.3)
The longest boarding patient's waiting period (h)	76.5 (60.0–102.0)	81.2 (47.5)	8 (8–8)	7.4 (17.4)	8 (8–8)	7.4 (16.7)	24 (24–24)	22.3 (26.2)
Number of intubated patients	0 (0–1)	7.0 (3.8)	0 (0–1)	7.0 (16.5)	0 (0–1)	7.0 (15.8)	0 (0–1)	7.0 (8.2)
The longest waiting time for examination (min)	66.0 (20.8–120.0)	7.7 (4.8)	66.0 (20.8–120.0)	7.7 (18.2)	66.0 (20.8–120.0)	7.7 (17.3)	66.0 (20.8–120.0)	7.7 (9.0)

ICU, Intensive Care Unit; IQR, Interquartiller range; NEDOCS, National Emergency Department Overcrowding Scale.
* Scenario 1: If all boarding patients were admitted immediately, Scenario 2: If all boarding patients were admitted within 8 h, Scenario 3: If all boarding patients were admitted within 24 h.

reducing hospital bed occupancy and enhancing patient flow can mitigate ED crowding [17]. Similarly, Asplin et al. emphasized the importance of addressing access blocks to improve ED performance, proposing strategies like improved bed management and coordination with inpatient unit [18]. Furthermore, the implementation of the 4-h National Emergency Access Target (NEAT) rule, as studied by Forero et al., showed a significant decrease in access block and an improvement in patient flow through the ED [19]. This rule ensures that patients are admitted, discharged, or transferred within 4 h of presentation to the ED, thereby addressing access blocks and reducing ED crowding. Forero et al. assessed the effect of the 4-h NEAT on 30-day mortality, access block, and chronic ED overcrowding in Australian EDs. Their study demonstrated that implementing the 4-h rule led to a significant decrease in access blocks, an improvement in patient flow, and a reduction in ED crowding.

Bein et al. examined the influence of patient volume and occupancy on access block during the COVID-19 pandemic in a Sydney-based ED [20]. They reported enhanced discharge and hospitalization rates within 4 h during the pandemic's initial phase (April–June 2020) compared to the pre-pandemic period. Furthermore, they reported that hospital occupancy rate and access block within 4 h in the ED had a two-fold more significant effect on the number of patients presenting to the ED and the number of patients arriving by ambulance [20]. We similarly identified that the primary contributor to ED crowding was access block, mainly due to the prolonged boarding times of patients waiting for admission.

Affleck et al. conducted a comprehensive analysis of ED overcrowding and access block, focusing on the contributing factors and potential solutions [21]. They proposed target times for addressing access block, including a median waiting time of 60 min for initial assessment and 4 h for patient admission, discharge, or transfer. In our study, the median waiting time for examination slightly exceeded the proposed target at 66 min, while the median waiting time for the patient with the longest admission duration was markedly higher at 76.5 h, significantly surpassing the 4-h target suggested by Affleck et al. Despite these differences, both studies emphasize the importance of addressing access

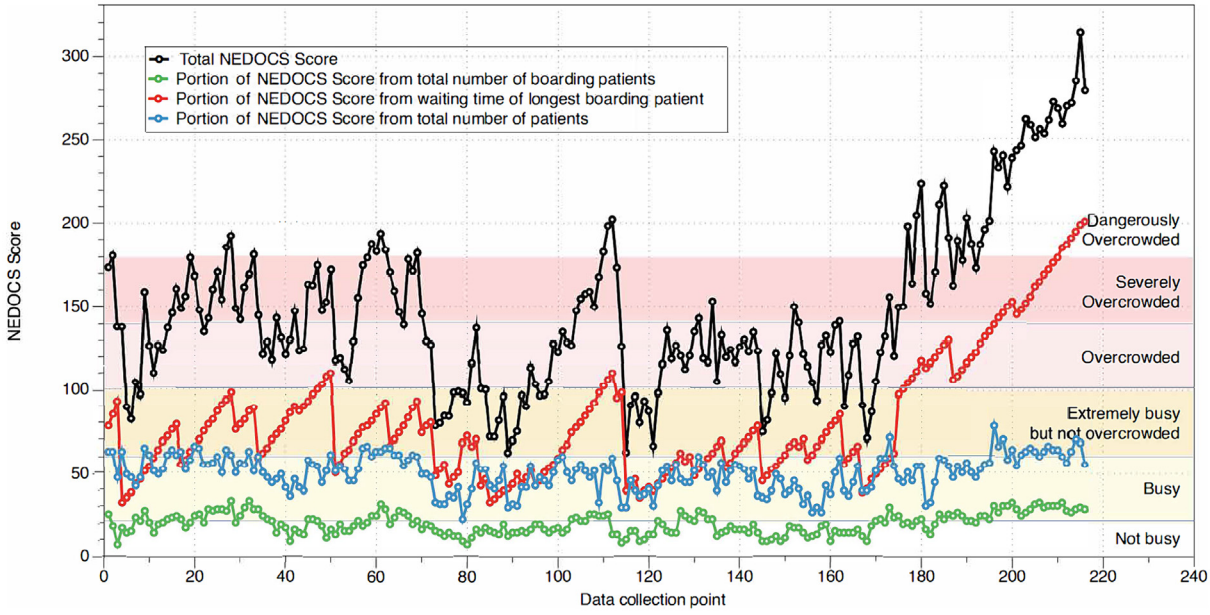

Fig. 2. The contribution of NEDOCS parameter on NEDOCS score on each data collection points.

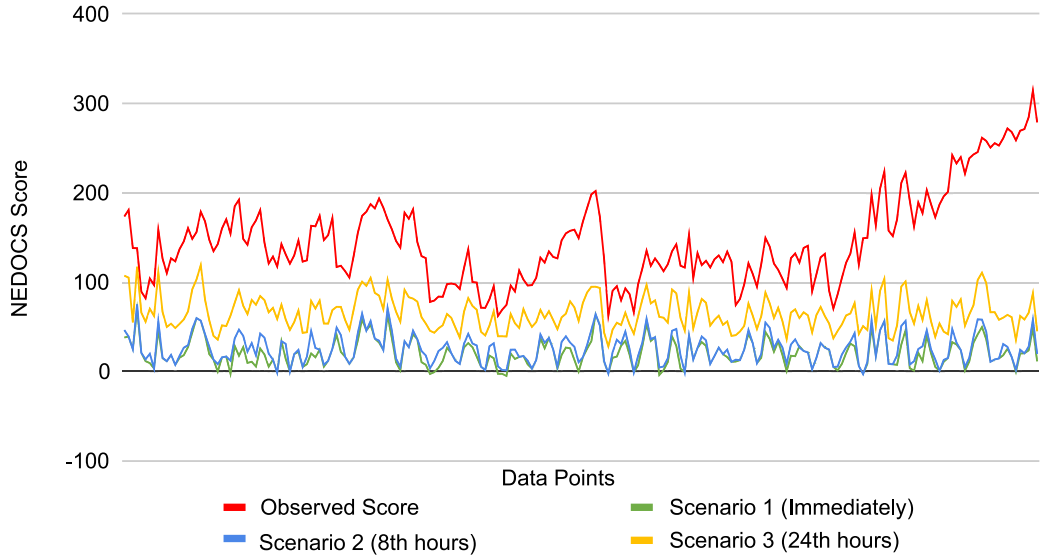

Fig. 3. Comparison of calculated and scenario NEDOCS for each data point.

blocks as a primary factor contributing to ED crowding. Our study, along with Affleck et al.'s research, highlights the need for healthcare facilities to implement effective strategies, such as enhanced bed management, coordination with inpatient units, and adherence to the 4-h rule, to alleviate access block and ultimately reduce ED crowding, improving patient care quality and satisfaction.

A comprehensive study by Taghizadeh et al. showed that as crowding in the ED increases, 30-day mortality increases, even in discharged patients. [22]. Therefore, it is essential to reduce ED crowding to provide healthy and effective emergency service care. Many strategies have been developed and tested to address ED crowding, including multidisciplinary approaches, machine learning, or artificial intelligence. Each focuses on a different cause and effect to reduce crowding [23]. In our study, the parameter that contributed the most to the NEDOCS score was the waiting time of boarding patients, with a rate of 47.5%. These waiting times should be shortened to prevent crowding in the ED. Therefore, early identification of patients in need of hospitalization in hospitals, accelerating the cycle within the hospital, and providing ED drainage seem to be the solutions that will contribute the most to the solution. For example, in their study, Seo et al. developed a practical, inexpensive, and helpful system for emergency physicians using machine learning [16]. With the system they have created, the average waiting time of patients can be estimated, and ED drainage can be achieved by ensuring that patients who need treatment for a long time are quickly admitted to the wards, relieving the ED crowding. Considering the time points of 8 h and 24 h in Scenarios 2 and 3 in our study, it is seen that the average ED crowding level decreased from 5–6 to 2–3. So, this scenario revealed that timely admission of boarding patients could substantially reduce ED crowding. Artificial intelligence and machine learning, which are increasingly widely used today, are thought to offer solutions to ED crowding [16,24].

The median longest waiting time for boarding patients requiring hospitalization was 76.5 h in our study, highlighting an inadequate capacity to meet hospitalization demand and a need for improved patient flow. In the study by Hammer et al., patients who could be discharged were identified by multidisciplinary rounding, and the average length of stay was shortened by 0.83 days. Reducing the inpatient length of stay with an increase in bed capacity is another parameter that can be a solution to the ED crowding [25].

Another issue considered effective is the additional services established to provide ED drainage, called “holding units.” These beds only serve emergency patients who need hospitalization from the ED and aim to reduce ED crowding. While patients wait for hospitalization from holding units to conventional units, a block is placed for elective patients to be admitted to other wards. Thus, it is planned to prevent elective patients from getting ahead of emergency patients. In the study by Vaquero et al., establishing a holding unit with 16 beds dramatically improved 55.6% in the number of patients waiting for hospitalization for 8 h and decreased access block [26].

4.1. Limitations

The principal limitation of this study is that it was conducted in a single center. Variability in the patient's length of stay in EDs across different hospitals further complicates generalizability. Additionally, the significant impact of boarding hours on the NEDOCS score precludes the applicability of this score in hospitals where waiting times in the ED vary. Multicenter studies are needed to eliminate this difference. This study was conducted over a specific time frame, and the findings may not apply to different time periods, especially given the dynamic nature of ED operations. Factors like staffing levels, other hospital policies, or even broader healthcare system issues might have influenced the findings but were not controlled for in our study. The unique circumstances of the COVID-19 pandemic, including the implementation of curfews, could limit the applicability of the findings to non-pandemic circumstances. The reliability and validity of the NEDOCS score may serve as a limitation, especially in settings different than the derivation study of the NEDOCS score.

5. Conclusion

While ED crowding is a multifactorial issue, studies and our findings highlight the critical importance of addressing access blocks to mitigate ED crowding. Through targeted interventions, improved patient flow, and resource management, healthcare facilities can better cater to their patient population's needs and elevate the overall quality of care provided in ED settings.

Compliance with ethical standards

This work was conducted ethically by following per under Helsinki World Medical Association Declaration.

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CRediT authorship contribution statement

Mustafa Altun: Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Emre Kudu:** Writing – original draft, Visualization, Software, Investigation, Formal analysis, Data curation. **Oguzhan Demir:** Writing – original draft, Visualization, Investigation, Formal analysis. **Sinan Karacabey:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Erkman Sanri:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Ozge Ecmel Onur:** Writing – review & editing, Methodology, Formal analysis, Conceptualization. **Arzu Denizbasi:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Haldun Akoglu:** Writing – review & editing, Visualization, Validation, Supervision, Software, Project administration, Methodology, Formal analysis, Conceptualization.

Data availability

The datasets generated during and/or analyzed during the current study are not publicy available, but are available from the corresponding author on reasonable request.

Declaration of competing interest

None.

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