REVIEW

Main Features and Control Strategies to Reduce Overcrowding in Emergency Departments: A Systematic Review of the Literature

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Purpose: Overcrowding is a problem that affects emergency departments (ED) all over the world; it occurs due to a disproportion between user demand and the physical, human and structural resources available. Essential prerequisites to assessing and managing the phenomenon are its accurate measurement and an understanding of its impact. The objective of this systematic review is to identify the characteristics of the problem, analyzing the proposed strategies aimed at improving patient flow, delay in services provided and overcrowding of emergency departments.

Methods: To achieve our objectives, a manual computerized search was performed in the bibliographic databases using as keywords "Emergency Department", "Overcrowding", "Emergency Room", "Emergency Service", "Emergency Unit","Emergency Ward", "Emergency Outpatient Unit", "Emergency Hospital", "Crowding", "Mass Gathering", "Management" and "Comprehensive Health Care". Two independent reviewers analyzed abstracts, titles and full text articles for admissibility, according to the selected inclusion and exclusion criteria.

Results: The process lead to include 19 articles. It was possible to group the solutions proposed in five categories: work organization, investment in primary care, creation of new dedicated professional figures, work and structural modifications and implementation of predictive simulation models using mathematical algorithms.

Conclusion: The most effective measures to guarantee an improvement in the flow of patients are represented by both improving the efficiency of human resources and by developing predictive mathematical models, regardless of the type of hospital and its location. Considering the complexity of EDs and the multiple characteristics of overcrowding and that the causes of crowding are different and site-specific, a careful examination of the specifics of each ED is necessary to identify improving fields.

Keywords: patients flow management, human resource efficiency, predictive mathematical models, patients overload, overflowing

Introduction

Overcrowding in emergency departments is a globally widespread problem. Technically, ED overcrowding occurs due to a disproportion between health demand, consisting of the number of patients waiting care, and the available physical and/or human and/or structural resources necessary to satisfy it.[1] It can also be defined as the situation in which the function of the ED is hampered mainly due to the excessive number of patients waiting to be examined, undergoing evaluation and treatment or waiting to leave, compared to the physical capacity or to the available personnel of the emergency room.[2] Among the main causes that affect patients' flow into an emergency room, the scientific literature reports the imbalances between the capacity of the ED and admission to triage for patients, the growing number of unscheduled emergency room visits,[3–5] large numbers of patients who persist in the expectation of receiving ongoing care in the ED for minor illnesses and excessive demand of diagnostic test.[5,6]

Both an accurate ED crowding measurement and an evidence-based understanding of the impact of ED overcrowding are prerequisites before attempting to find solutions. The best-known models of the emergency system are based on 3

macro phases:[7] the volume of patients arriving (input), the time to process and/or treat patients (throughput), and the volume of patients leaving the ED (output). Any combination involving a rise in input, a delayed throughput, or a decreased output can lead to crowding.[8] The input phase refers to an excessive and significant ED-access of users, determined in recent years by the onset of new care needs, which can take place urgently by ambulance, by nursing homes, by family or by specialized doctors, by police or by autonomous choice. The throughput phase refers to a slowing down of the ED internal pathways, and in particular of the triage phase, medical examination, and all the diagnostic activities that require the collaboration of specialized consultants. Finally, the output phase includes both the difficulty in hospitalizing due to unavailability of a bed in the destination ward, and the difficulty in discharging the patient, inevitably causing the length of hospitalization to be prolonged.[1]

The input, throughput and output factors can determine a prolonged stay of already-evaluated-patients inside the ED, waiting for the bed into a specialize ward. This phenomenon is already known as "boarding", and it determines a considerable absorption of operational resources within the emergency services; this has consequences for patients, health care operators and for the system as a whole. Table 1 reassumes the main variable influencing each of the three phases of the emergency system (Table 1).

Despite the efforts employed and the knowledge acquired so far, the problem of ED overcrowding persists globally, demonstrating how few evidence-based-solutions have been achieved to improve the flow of patients in ED, with a growing attention to the use of simulation models, predictive algorithms and artificial intelligence aimed at optimizing the resources already present.[9,10] The objectives of this systematic review is to I) identify overcrowding features, II) analyze the proposed strategies aimed at improving the flow of patients, the delay in services provided and the ED overcrowding.

Materials and Methods

In this review article, we performed a computerized database search to identify relevant articles. We searched for published articles in bibliographic databases, including PubMed, Scopus, Web of Science (last search on 29/01/2022). A manual search of bibliographies of the identified papers and relevant information to meet the objectives of this study

Table 1 Main Causes of Ed Overcrowding Broken Down by Factor

Phase	Influencing Variables
Input	Population aging with increased demand for hospitalization
	Difficulties in accessing urgent healthcare services
	Distorted information provided by mass media
	Bad health education
	Mismanagement of treatable diseases at home
	Lack of seasonal disease prophylaxis
	Inappropriate hospitalization request
	Increase of the poor population with consequent difficulty to face health costs
	Failed intervention on ED Frequent Users
Throughput	Failure to optimize triage activities
	Architectural limits of ED department
	Excessive practice of defensive medicine
	Efficiency of diagnostic services
	Health care understaffing
	Collaboration lack between health personnel
Output	Hospital bed shortage
	Failure to identify available beds
	Shortage of hospital discharge rooms
	Delayed and prolonged discharge
	Lack of social services to facilitate difficult patients' discharge

was performed. Two independent reviewers screened abstracts and titles for eligibility. When the reviewers felt that the abstract or the title were potentially useful, full copies of the article were retrieved and considered for eligibility by both reviewers. When discrepancies occurred between reviewers, the reasons were identified, and a final decision was made based on a third senior reviewer agreement. Keywords used in the search were "Emergency Department (ED)", "Overcrowding", "Emergency Room", "Emergency Service", "Emergency Unit", "Emergency Ward", "Emergency Outpatient Unit", "Emergency Hospital", "Crowding", "Mass Gathering", "Management" and "Comprehensive Health Care". The selection of these terms was made by MeSH service in PubMed website databases. Thus, we obtained 436 articles from PubMed, 623 articles from Scopus and 73 articles from Web Of Science, for a total of 1132 articles. By loading each bibliographic database's search extract files (.bib and.nbib) into the Zotero tool, 145 duplicates were eliminated.

An additional 708 records were excluded after applying the title and abstract eligibility criteria, while 80 articles were excluded for other reasons (for example: paid access). The full texts of 199 articles were reviewed. Of these, 163 articles met the inclusion criteria and were evaluated for eligibility, and 36 articles were excluded because they were too specific, as they examined the problem of overcrowding exclusively in relation to particular clinical conditions (for example: opiate intoxication, cardiac arrest, following traumatic episodes or in conjunction with large mass events).

After reading the full text and in light of the eligibility criteria (Table 2), 19 studies were included in this systematic review. Figure 1 shows the search and selection process according to the PRISMA 2020 statement[11] (Figure 1 and checklist reported in the Supplementary File).

The independent reviewers manually extracted the data, that was inputted into a standardized excel database, in which, for each included article, were inserted article title, authors, year of publication, time period analyzed, duration of the observation period, country, scientific journal, type of article, causes, consequences, overcrowding measurement scales, solutions, presence or absence of simulation models, predictive algorithms, artificial intelligence, outcomes of the improvement actions undertaken, study limits and macro phases involved (input, throughput, output).

The literature search was limited to journal articles and governmental documents in English, German and Italian, with a time horizon between 2012 and 2022. The main reasons for exclusion were: (1) correlation between ED overcrowding and the prevalence of acute or chronic diseases/disorders, (2) impact of Sars-Cov2 virus on ED overcrowding, (3) systematic reviews, (4) descriptive articles without solutions on the overcrowding problem and (5) pediatric hospital/ pediatric age.

Results

With regard to timeline set (2012–2022), 11% of the articles were published in 2012, 16% in 2014, 5% in 2015, 11% in 2016, 21% in 2018, 16% in 2019, 5% in 2020 and 16% in 2021. From full text reading of the 19 articles, we extracted the observation period of the overcrowding phenomenon for each study, resulting in an average of 903.47 days with a minimum interval of 14 days and a maximum of 4382. The selected articles come from 11 different countries, among which the USA (39%) and Taiwan (11%), and the most represented type of article was observational study (53%) (Figure 2).

Table 2 Elegibility Criteria

Inclusion	Exclusion
Timeline 2012–2022	2011 ≤ Time > 2022
Age ≥ 13 anni	Age ≤ 12
Articles with proposed solutions	Systematic Reviews, Descriptive articles without solutions
English, German, Italian languages	Languages other than English, German, Italian
	Relationship between Sars-Cov2 virus and ED overcrowding
	Correlation with acute or chronic diseases/disorders

Figure 1 Flowchart of the search and selection process of articles according to the PRISMA statement. No automation tools were used to screen articles.

Overcrowding indicators are classified as outcome indicators or process indicators within the emergency room, and also divided in static, dynamic or temporal dynamic.[1] We identified these indicators in each article as reference to manage and monitor the phenomenon. In particular, on a total of 27 measurement scales found (Figure 3), the most represented are ED LOS (Length of Stay, 24%), LWBS (Leaving Without Being Seen, 9%) and the Door to Evaluation Time (9%); moreover, causes and consequences of ED overcrowding have been classified (Table 3).

During data extraction, to investigate ED overcrowding causes and consequences, it was necessary to make data homogeneous by grouping each result into macro categories; therefore, as reported in Figure 3, we divided them into: managerial causes (57%), human causes (40%), structural causes (3%) and technological causes (0%). Data relating to the consequences show those on patients (51%), on the system (27%) and on healthcare workers (21%) and not analyzed data (1%). Regarding the

Figure 2 Source and type of articles selected for the review study.
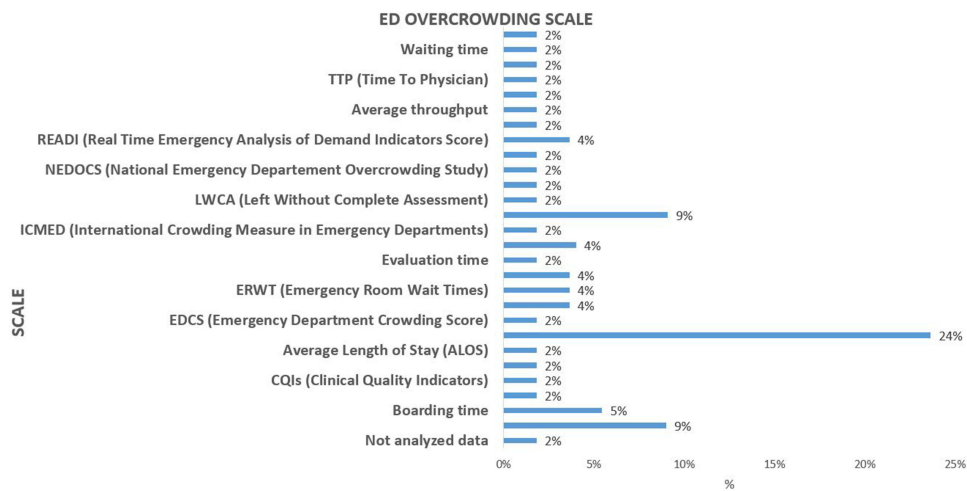
ED OVERCROWDING SCALE

Figure 3 Measurement scales used as indicators to monitor the phenomenon of overcrowding.

analysis of the strategies identified to overcome the problem of ED overcrowding, each proposed solution was classified on its area of influence on the input, throughput and output processes (Table 4). The strategies implemented to overcome the ED overcrowding focused on new solutions to improve the ED internal pathways (throughput), which represent 65% of the total, compared to the input (12%) and output (23%) (Figure 4).

Discussion

From the selected articles, it was possible to group the proposed strategies into macro categories: work organization, investing in primary care, creation of new dedicated professional figures, structural works and modifications and implementation of simulation predictive models using mathematical algorithms. A deeper discussion by macro-categories follows.

Work Organization

Many scientific articles aim to compare how the number of ED patients involved in throughput and output can affect patients waiting time on input.[5] Although in the literature there are studies that demonstrate how to improve the throughput processes, it is necessary to keep in mind that there are differences in the triage organization, when considering different countries.[12–14] Therefore, it is important to use a continuous, rigorous, standardized monitoring of the activities implemented, employing

Table 3 Causes and Consequences of Ed Overcrowding

Causes	Item
Structural causes	Shortage of ED physical space[3,4,10]
Technological causes	–
Human causes	Increase in unscheduled access[3,5,9,11–13]
	Inadequate ED access[5,6,10,13–17]
	Increase of elderly people[15,16,18,19]
	Increased demand from patients for specialized care[11,17,18]
	Rising burden of chronic disease[19]
	Excessive diagnostic test demand[5]
	Defensive medicine[6]

(*Continued*)

Table 3 (Continued).

Causes	Item
Managerial causes	Rising Emergency Department closures[3]
	Increased patients waiting to be hospitalized[5,15,17]
	Insufficient numbers of health workers[4,10,13–15,20]
	Lack of availability of beds[3,4,6]
	Flow patients' Bad management[12,17,21]
	Ambulance diversion[22]
	Mismanagement resources allocation[10,16,20]
	Limited access to primary care[15]
	Reduced health funding[13]
	Inability to discharge patients[6,13,23]
	Delayed services and consultations[4,16,21,24]
Outcomes	
On patients	Increased in-hospital death[4,12,14,15,19,20,23,24]
	Increased patients who left without complete assessment[24]
	Increased patients leaving the emergency room without being seen[10,12–14,16–18,20,22]
	Increased patients' pain and suffering[22]
	Patient dissatisfaction[13–15,17,19,21–23]
	Delay treatments[16,17,23]
	Inbed delay patients[16]
	Delay in identification and treatment[6,12]
On healthcare workers	Increased of the preventable medical mistakes[22]
	Health workers burnout[14,17,19,20]
	Decreased quality of care[6,11,16,17,21]
	Work related stress[20]
On the system	Maximum waiting time for medical examination > 4 h[13]
	Prolonged ED Lengths Of Stay[3,4,10,14–16,18,19,23,24]
	Rising health care cost[12,13,16,17,21]
	Increased waiting time[6,12,22]
	Ambulance diversion[12,21]
	Waste of medical resources[6]

analytical strategies to evaluate the results.[5] At this stage, work organization is comparable with optimization of staff and resources already present, especially when financial tension and limited resources challenge hospitals to provide timely and effective care.[3–15] Beyond optimizing available resources, the most effective strategies to reduce overcrowding are early and targeted interventions, such as: earlier identification of subtle presentations of life threats, earlier starting of diagnostic testing, earlier administration of important therapies,[12] real-time information on ED overcrowding,[16] creating a tool that predicts waiting

Table 4 Proposed Solutions to Overcome Ed Overcrowding

Actions involving input	Ensuring priority of hospitalization for ED patients[4]
	Transfers between institutions permitted only if there are no patients awaiting admission in the ED[4]
	Ambulances diversion to other hospitals presumed less crowded[18]
	Incentivizing patients with less serious conditions to see their family doctor first, before going to the ED[16]
	Addition of clinical assistant to each ED shift[22]
	Investing in primary care[16,17]
	To build home care and post acute care resources such as long-term care or rehabilitation services[6]
	Forecasting emergency department flow[3,10,17]
	Transference of admitted patients out of the ED rooms and into inpatient hallways[15,19]
	Discourage boarding of admitted patients in ED exam rooms[14]
Actions involving throughput	Time-series analysis used to develop statistical models in order to forecast the patients flow in the ED[10]
	Increase bed of internal medicine[19]
	Increase outflow of internal medicine patients from the ED to the internal medicine departments[19]
	The access block viewed as a whole hospital problem and not only an ED problem[23]
	The creation of a Patient Partner role[21]
	Adding a dedicated triage space for patients who arrive by emergency medical services (EMS triage)[13,14]
	Establishment of a rapid assessment unit (RAU) in ED[21]
	Decrease requests for unnecessary advance diagnostic tests[5]
	Development of a dashboard which provides real-time information regarding ED crowding[20]
	Early identification of events that may worsen patient's health[24]
	Create a real time tool to inform patients about waiting times[17,22]
	Improve the ED information system[5,6,20]
	Improve patients post acute care[6]
	Having a comprehensive view of patient flow in ED[3]
	Optimize staff and resources[3,10,15,18,23]
	Implementing additional resources and alternate care pathways[3]
	Hospital beds priority at ED[4]
	Patients registration process simply and fast[15,21]
	Early identification of patients needing hospitalization or discharge[24]
	Earlier administration of important therapies such as analgesia and antibiotics[24]
	Close monitoring of specialties with the highest percentage of emergency room visits (cardiology, gastroenterology and pulmonology)[11]
	Supplemented Triage and Rapid Treatment (START)[24]
	Improve triage effectiveness[12]
	Speed up the request for necessary diagnostic tests[5,24]
Actions involving output	Increased partnerships with social care service providers to facilitate discharge[13]
	To follow in the clinic patients already evaluated for the first time in the ED[11]
	Discharge of ED patients before 12:00 and discharge of internal medicine patients by the morning shift[19]
	Review of all patients in hospital for 14 days or more[13]
	Decanting non-emergency lower acuity patients from the ED to a primary care clinic[16]

times to inform patients,[17] reducing the number of potentially avoidable diagnostic tests and treatments performed,[5] discharging patients before noon,[18] re-evaluating all patients staying in hospital for 14 days or more to facilitate their discharge.[19] The proposed solutions, although effective, are not exempt from evident limitations: arbitrary choice of ED LOS threshold values,[16] changes implemented only in an urban and medium-sized ED,[20] implementation of improvement actions in an ED already functioning,[18] ignoring ED patients' satisfaction or the impact of physician bias on waiting time.[21] However, the limitation regarding the choice of ED LOS cutoff values could easily be overcome by focusing on the interactions between the different factors constituting the rating scale, as these allow a deeper analysis for planning, thus improving decision-making.[22]
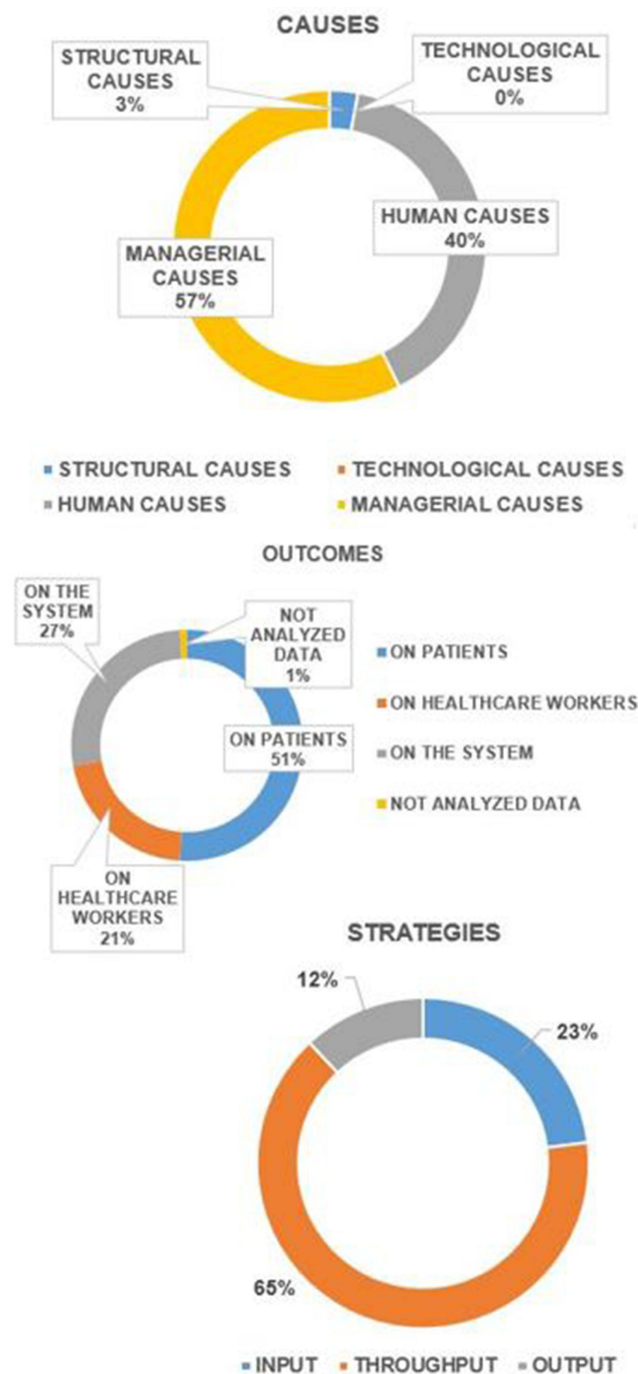
CAUSES

STRUCTURAL CAUSES 3%

TECHNOLOGICAL CAUSES 0%

HUMAN CAUSES 40%

MANAGERIAL CAUSES 57%

- STRUCTURAL CAUSES
- TECHNOLOGICAL CAUSES
- HUMAN CAUSES
- MANAGERIAL CAUSES

OUTCOMES

ON THE SYSTEM 27%

NOT ANALYZED DATA 1%

ON PATIENTS 51%

ON HEALTHCARE WORKERS 21%

- ON PATIENTS
- ON HEALTHCARE WORKERS
- ON THE SYSTEM
- NOT ANALYZED DATA

STRATEGIES

12%

23%

65%

- INPUT
- THROUGHPUT
- OUTPUT

Figure 4 ED overcrowding: identified causes, consequences and implemented strategies.

Investing in Primary Care

As both the population age and the burden of chronic disease grows, people need complex care, that should be organized according to an accessible care pathway model.[23] A difficult and delayed access by patients to diagnostic tests prescribed by their family doctor can lead to improper ED use and its consequent overcrowding. Ansah et al[24] and Ferreira Amorim et al[17] concluded that there is an inappropriate ED use and that an enhanced primary care system is needed to reduce ED crowding. Indeed, Wang et al[6] found that families continue to use ED to obtain care for elderly or disabled patients, whose needs should be met in a long-term care facility.

A strengthened primary care system has the potential to improve population health outcomes and, consequently, to reduce the demand for non-emergency care in the ED. In view of these results, the involvement of political leaders is essential to design a cost-effective way to improve primary care and to co-locate general practice clinics across all EDs, to which all non-emergency patients may be sent.

Creation of New Dedicated Professional Figures

Several authors agree that it is very important to involve and train staff[19,20] before successfully designing and implementing new improvement actions; therefore, new dedicated professional figures have been proposed to contribute to both the physical and structural changes in ED, and the reorganization of patients' flow. For instance, the figure of the *patient partner* emerges; this new figure is focused on the initial presentation of the patient, positioning of the bed, quick registration of the patient on the computerized medical record.[20] It is also recommended a rapid evaluation unit (RAU), medical evaluation, complete registration at the patient's bed after medical visits and nursing services, patient stabilization and start of treatment.[20] Therefore, it is important to invest in training the personnel already hired and in relocating doctors and nurses already assigned to triage in the RAU.

In order to significantly improve the flow of patients, decrease the workload of healthcare personnel and increase the patient experience, a patient-centered care model has been also proposed, requiring limited healthcare costs. A similar solution is proposed by Huang et al[21] with the identification of a *clinical assistance*, a professional figure in charge of managing the flow of incoming patients, entrusting them in an orderly and efficient way to doctors, informing them of expected waiting times and managing the anxious states that patients and their relatives may present. At the same time, this so-called *clinical assistance* was involved in all administrative matters, as it helped the patients in the compilation of required forms and in answering all non-medical questions. The study shows how, in a crowded ED, the introduction of the professional figure of the *clinical assistance* effectively reduces both ED LOS and the number of patients who leave ED without being seen by healthcare workers. Finally, the need to involve social assistance services in multidisciplinary meetings about long-term hospitalizations, to facilitate difficult discharges, is transversal in the literature.

Structural Works and Modifications

ED transformation is considered a manageable, strategic, economic, and sustainable solution, and has a positive impact on both patient care experience and input factors. In addition to the ED structural changes, the number of beds in the internal medicine wards should be increased, with the clear intention of improving discharge from the emergency room in the morning,[25] and avoiding boarding. Valipoor et al,[26] limiting their analysis to the structural environment, identified strategies for assessing the impact of ED crowding and long waiting times, such as a reorganization of internal spaces to ensure first patients' evaluation, using hallway beds/chairs and enlarging the triage area dedicated to emergency. Similarly, in Stanford ED,[18] an ED vertical flow model was created, removing fold-down horizontal stretchers and replacing them with multiple chairs that allowed for the assessment and medical management in an upright sitting position. Each structural change undertaken has shown to be statistically effective in reducing ED overcrowding, but has also resulted in conflicting effects, such as increased dissatisfaction among the medical and nursing staff due to an increased number of admissions in a limited number of hours.[25] Moreover, the expansion of the triage area may not be as effective in other EDs,[26] where the problem regard human resources, rather than the physical expansion of ED spaces.[20]

Implementation of Simulation Predictive Models Using Mathematical Algorithms

In the last two years, digital information around the world has more than doubled, and this trend is likely going to increase exponentially. Medicine is the protagonist of this growth. This is demonstrated by the explosion of the IoMT (Internet of Medical Things) and by the use of new analysis models, such as machine learning techniques, to learn from data, with the final aim to generate predictive models[27] that allow to understand that certain combinations of values can provide the solution of the problem in real time. According to these premises, also in the analyzed literature, there is a wide use of simulation models. Ansah et al[24] employed the dynamic system (SD), creating virtual simulation models in order to develop and test the solution strategies before their implementation. Simul8[17] is a model also capable of generating solutions to help healthcare managers to improve ED overcrowding in different scenarios. This forecasting

and simulation model is able to predict the patient's requests for admission and ED waiting time, to assist in human resources planning, process design, to guide educational strategies for staff and to improve decision making of health care managers.[17] The simulation of discrete events (DES)[26] is another model used to explore the impact of the implementation of different strategies on ED flow patients. Another system that acts primarily on productivity is the Dynamic Grouping and Priority Algorithm (DGP),[28] which identifies the most appropriate patient groups for hospitalization, assigning them a priority level based on patient information and organization of the ED in real time.[28] Considering the diversion of ambulances[29] to nearby hospitals as a last resort to temporarily alleviate ED overcrowding, Lin et al[30] developed a simulation series system to evaluate starting criteria and deviation intervals, analyzing the access block causes, crowding index, patients LOS (Lenght of Stay), probability of adverse events and the effect of the choices made to solve the problem.

The Experience in a Hospital Reality

This systematic review gave to the authors an opportunity to proceed with a careful analysis of the organization of the ED of our hospital, which is also afflicted by the problem of overcrowding. In this historical period, in which there is a chronic shortage of medical staff, it is essential to guarantee the best effectiveness of the resources already available. In agreement with the results obtained, and considering the computerization process already underway, we focused on input \throughput factors. In collaboration with the service of clinical engineering, we have expanded the ED premises, renovating them in order to obtain a waiting room with an info-point distinct from the triage area. In this way, we were able to ensure greater efficiency in the management of low priority tags, improving the triage working condition, and providing timely information on the status of patients' health to family members, thus also limiting episodes of violence against healthcare workers. Training courses were carried out for both nursing and medical staff, implementing a random monitoring system of the ambulance block in the emergency room.

At the same time, based on historical data on the ED access, we are trying to evaluate the best mathematical model to timely predict the highest risk of overcrowding and implement the stated preparedness plan. Time will tell us what has been implemented.

Conclusion

The problem of ED overcrowding is extremely widespread, and the effort that health authorities and governments are making to counteract this problem is undeniable. Although the number of selected articles is limited, it is enough to conclude that the most effective weapon to ensure a significant process of improving patients' flow in ED is represented by improving efficiency in human resources and in the technological development of predictive mathematical models, regardless of the type of hospital and its location. Healthcare professionals should be directly involved, informed of the strategies undertaken to combat ED overcrowding and properly trained to expand their skills and responsibilities. Considering that causes of ED crowding are variable and require site-specific solutions,[3] but also considering the complex nature of emergency departments and the multiple characteristics of overcrowding, a careful examination of the specific functioning of each ED is necessary to identify the negative impacts, improve treatment time and patience experience, and to plan strategies to combat the phenomenon by acting on input, throughput or output.

Disclosure

The main limitation of this review is the limited number of article selected, followed by the variability in study design and methodological quality of included articles. The observational studies included varied in the quality of methodology descriptions, outcome evaluation, and reporting: this made the comparison between studies' results difficult. Moreover, this study included only articles written in English, Italian and German; therefore, some pertinent studies may have been excluded. This research received no funding. The authors report no conflicts of interest in this work.

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