**Review Article**

# Strategies For The Management Of Ambulance Diversion And Emergency Department Overcrowding: A Systematic Review

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**Abstract**

The issue of overcrowding in emergency departments stands out as a critical concern in overpopulated cities. Access block is defined as situations when patients in the emergency department (ED) have no access to appropriate hospital beds within reasonable time despite their needs for inpatient care, leading to overcrowding and ambulance diversion (AD). AD is regarded as a controversial strategy to alleviate ED congestion, curbing the input visits and is executed as a measure when EDs request ambulances to transport the patients to less crowded hospitals. This systematic review gathered the main strategies which are applied in the real world to decrease AD and ED overcrowding. An exploration of PubMed, Medline, and Web of Science databases was undertaken to scrutinize articles from November 1-25, 2020. Eventually, we found 18 pre and post-intervention studies which developed strategies in real situations to decrease AD in an attempt to reduce ED overcrowding. The findings pointed to the enhancement of agency capacity whether by increasing the number of beds in the emergency room or developing an acute care unit (ACU) as a new form of controlling patient flow at the back end of the ED using the AD ban and no-diversion policy, formation of improvement teams, collaboration of hospitals and emergency medical services agencies, and determination of optimal patient destination by a destination-control physician as the main strategies to reduce AD in order to increase ED overcrowding.

**Keywords:** Medical services agencies, Emergency department, Overcrowding, Ambulance diversion.

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## Introduction

Emergency department overcrowding is one of the daunting challenges in overpopulated cities. Although there is no clear definition for overcrowding, it accounts for more than 90% of congestion in medical centers; therefore, it should be considered a worldwide crisis (1, 2). Access block is defined as a situation when patients in the emergency department (ED) have no access to appropriate hospital beds within reasonable time despite their needs for inpatient care, leading to overcrowding and ambulance diversion (AD) (3). Although the number of specialists from different disciplines is increasing, it is stable or even decreases for care physicians (4). The discrepancy between supply and demand is the main cause of ED overcrowding which imposes a huge burden on the staff and is dangerous for the patients. The main consequences of ED overcrowding include hallway patients, consistent occupation of ED beds, recurring extended wait durations throughout the week, undermined clinical care, and increased mortality rate (5). Based on surveys conducted by hospital directors, 91% of hospitals in almost all states of the USA had overcrowded EDs. In the USA, 10-30% of hospitals are faced with daily overcrowding. In this regard, primary reason for overcrowding in emergency departments is often attributed to the incapacity to efficiently shift urgent cases to available inpatient beds. Ambulance diversion, the frustration of patients and ED staff, and greater risk for poor outcomes are the main potential detrimental effects of overcrowding (6). EDs facing excessive crowding induce congestion through the redirection of ambulances and the augmentation of turnaround times. Lee et al. found an adverse correlation between the state of overcrowding and the time it takes for turnaround processes (7); nonetheless, varied findings have emerged, indicating correlations between the overcrowding of EDs and turnaround time. This inconsistency is attributable to divergent ED cultures and policies, alongside the increased likelihood of patients spontaneously vacating stretchers within a congested ED setting. Based on previously conducted studies, ED overcrowding can be relieved by the management of patients' entry, progression, and exit within ED (8-12). According to a survey conducted on medical care within national hospital ambulatory settings, about fifteen percent of total ED visits are related to the patients arriving by ambulance (13, 14). Addressing ED congestion, AD presents a contentious approach by mitigating overcrowding through the reduction of the input component (15) and is performed when ED asks for ambulances to take patients to less crowded hospitals. The assessment of AD effectiveness in the real world is difficult when the ED overcrowding increases. Patients' average waiting time and percentage of time spent on diversion are two main criteria for the assessment of the effect of AD on ED (16). The present study aimed to gather the main strategies that are applied in the real world to decrease AD and ED overcrowding and determine the main advantages of these strategies and approaches in resolving these problems.

## Methods

This systematic review was performed to assess the strategies which are applied to decrease AD in an attempt to reduce ED overcrowding. Cochrane Handbook for Systematic Reviews of Interventions was used in various stages of the present study, including determination of inclusion and exclusion criteria, searching process, excluding the unrelated articles, evaluating the quality assessment, extracting data, and discussing (17).

### Eligibility Criteria

In the current review, Participant-Intervention-Comparison-Outcome-Study design was used to select the eligible articles. We included all pre and post-intervention studies which provided strategies in a real situation to decrease AD in order to reduce ED overcrowding. We only entered papers published in English; moreover, the articles with no clear data and those with unavailable full text were excluded. In addition, we included only articles in which a proposed

strategy was conducted in a real situation (e.g., hospitals, EDs, or health centers) for decreasing ambulance deviation, and those studies which assessed the effects of other factors (e.g., blockage of access) on overcrowding were excluded. Time series modeling and studies which presented a simulated model or a technical model without its examination in real situations were also ruled out from this project. Moreover, we restricted all studies in which the condition of ambulance deviation and overcrowding was not assessed before implementing or operating the proposed strategy. Regarding the research design, we entered only pre-post interventional studies and excluded all other types of observational, interventional, and review studies or letters and books.

**Literature search**

A An exploration of PubMed, Medline, and Web of Science databases was undertaken to scrutinize articles from November 1 to November 25, 2020. These keywords were used for query: “overcrowding” and “crowding” “ambulance deviation” paired with "emergency", "emergency department", and "emergency room". Two expert researchers were continually in contact with each other to come to an agreement all stages of work.

**Study design and data extraction**

All the articles which proposed strategies for decreasing AD and ED overcrowding were included in the present systematic review. The selected aforementioned keywords were applied to search all papers published up to November 25, 2020, in PubMed, Medline, and Web of Science databases. Moreover, some articles were obtained by manual search. After the research process, the articles inconsistent or unrelated to the research objective were excluded from the study. Subsequently, we prepared a reference list of related primary articles, found the duplicates articles, and removed them. In the next step, the titles and abstracts of the articles were studies to remove those not meeting the eligibility criteria. We obtained the full-texts of papers for future evaluation and then removed the articles with insufficient data or those which were not focused on our objectives. The whole process was performed by two researchers who were continuously in contact with each other to come to an agreement on the eligibility criteria, data extraction, topic issues, and the objectives of the study. Finally, we reviewed the context of the selected articles to obtain data on the strategies proposed to decrease AD in an attempt to reduce ED overcrowding and offered recommendations for further study in this area. The collected data (i.e., location, type of study, sample size, strategies for resolving AD, duration of the intervention, changes in AD time, and outcome) were extracted from the articles and inserted in a Table, as illustrated in the result section (Table 1). All the stages of article selection are represented in the PRISMA flowchart (Figure 1).

**Risk of bias and quality assessment**

In the current review, the guidelines of the Cochrane were used to determine the risk of bias or quality assessment. We evaluated seven categories of the guidelines, including bias due to confounders, selection of the sample, the measurement of intervention, missing data, selective reporting, and other sources of bias (18). We assigned the studies to three categories of high, low, and undetermined based on their quality. Figure 2 depicts the quality assessment of the included articles.

**Results**

Out of 2061 retrieved articles, a total of 1,764 papers were excluded on grounds of irrelevancy. Within the remaining pool, 62 studies were identified as duplicates and consequently eliminated, while the remaining articles underwent thorough eligibility evaluations. We also excluded 3 studies since they were published in other languages. Among the remained articles, 74 articles which proposed simulation strategies to decrease AD in order to reduce ED overcrowding, time series modeling, and technical models that were not examined in a real situation were excluded. Moreover, we ruled out 11 studies in which the condition of AD and overcrowding was

not assessed only after implementing the proposed strategy. Furthermore, 214 papers were also eliminated based on the reason of exclusion in figure 1. Eventually, we came up with 18 pre and post-intervention studies which proposed strategies in a real situation to decrease ambulance diversion in order to reduce ED overcrowding (Figure 1).

Nine of the selected studies were conducted based on a retrospective design (50%), and nine of them were prospective (50%). The predominant geographic focus of the investigations was in North America, predominantly in the United States, accounting for the majority (89%), followed by a smaller percentage (5%) in Canada. Moreover, one study was performed in Taiwan. The included studies were carried out on a range of 1,589 to 723,000 patients in EDs. The duration of trials ranged from two weeks to three years. The patients who left without being seen (LWBS) were reported as 10-40% in various studies. The range of decreased AD time in various studies was estimated to be between 18%-92% h. Length of stay for admission decreased from 523-454 h one year after the intervention in a study performed by McConnell et al. (19), and it was decreased from 15.02-11.78 h in the study conducted by McLeod et al. (20). This decrease was reported as 25 min on average in a study conducted by Yancer et al. (21). Burke et al. reported a 10.4 min decrease in length of stay after the intervention (22). This decrease ranged from 4.1-3.7 h (23) and 9.7-8 h (24) in the studies conducted by Watase and Lee, respectively. Moreover, the mean difference of decreased length of stay for admitted patients was calculated at 0.30 h in the study by Friedman et al. (25).

In general, three studies (16.7%) tried to manage ED overcrowding by increasing the number of beds in the emergency room or developing an acute care unit (ACU) as a new form of controlling patient flow in the back-end of ED (19, 24, 26). Moreover, 39% of papers (seven studies) suggested using the AD ban and no-diversion policy to decrease AD in order to reduce ED overcrowding (22, 25, 27-31). Moreover, improvement teams were formed in 4 (22%) papers to decrease AD (21, 23, 32, 33). Moreover, 2 (11%) papers referred to the collaboration of local hospitals and emergency medical services agencies as other strategies to decrease AD in order to reduce ED overcrowding (34, 35). Furthermore, the determination of optimal transport destination for patients by a destination-control physician was proposed by two studies (20, 36). Table 1 displays the extracted data from each study.

**Discussion**

In general, the factors which lead to ED overcrowding can be assigned to three main categories, namely input, flow, and outflow. Input factors include the excessive influx of patients at EDs occurring due to various reasons. The impossibility of family doctor visit is one of the main reasons for -n-urgent visits to EDs. Influenza season, alcohol overuse, previous hospitalization, and the presence of chronic diseases are the major reasons for frequent flier patients (higher than 4 consultations per year) (37, 38). In addition, overcrowding is affected by the income status of the population, as well as demographic and migration factors (4, 39). Flow factors include anything that delays ED patient flow endangering the lives of patients, including staff shortages and diag-stic delays. On a final note, outflow factors refer to insufficient outflow of the patient to the extent that requires the management of situation (40).

Potential solutions, increasing capacity, and improving efficiency are three main issues that should be considered to decrease ED overcrowding. The Emergency Department Work Index (EDWIN) emphasizes physicians and nurses' perception of overcrowding and diversion considering the number of patients, physicians, and empty beds (41). Inability to move admitted patients from the ED to an inpatient bed is the main cause of ED overcrowding (42, 43). The number of patients boarding in the ED and the boarding time increased the AD; accordingly, the

ED throughput time increased to 18 min with a 10% increase in inpatient occupancy (44). Increasing capacity is regarded as the first solution for the management of ED overcrowding (45). One study showed that a 43% increase in the number of ICU beds decreased AD hours by 66% (46). On the other hand, based on the Joint Commission on Accreditation of Healthcare Organizations (JCAHO), ED visits for -n-urgent conditions is the other main causes of overcrowding (47). This highlights the need for the improvement of efficiency as a solution for ED overcrowding (48).

**Increasing Bed Capacity for Decreasing Ambulance Diversion**

Drawing conclusions from a research study conducted by the Advisory Board Company, it was identified that patient care encounters a minimum of 19 distinct bottlenecks or potential points of delay (49). These can be broadly classified into three primary factors: front-end, ED operations, and back-end. The findings suggest that addressing issues at the front-end has a moderate impact on managing overcrowding and may marginally defer the occurrence. In contrast, challenges at the back-end contribute to the most significant and prolonged delays. Consequently, implementing solutions targeted at resolving back-end issues is anticipated to yield the most favorable outcomes (49).

Kelen et al. developed an acute care unit (ACU) as a new form of controlling patient flow at the back-end of ED. In the aforementioned study, due to the necessity of expanding ED capacity and controlling patient flow. In the next step, a 14-bed ACU consisting of a good waiting room was located within an appropriate distance of ED. The new ACU is completely managed by the Department of Emergency Medicine and only ED personnel are accommodated in the unit. The results pointed to a reduction in LWBS rate and ED diversion, compared with the previous year before opening the new unit (26). However, we can't dispute that the new unit represents a back-end solution or yield an increase in capacity.

A study conducted by McConnell et al. indicated that an increase in ICU beds from 47-67 (43%) led to a 66% decrease in AD hours (from 3.8-1.3 h). A less considerable change was observed in ED length of stay, and the largest decrease (average 25 min) in ED length of stay was observed in ICU patients. They demonstrated that most ED crowding related issues can't be resolved by increasing ICU capacity (19). In another cohort study conducted in Taiwan, only 14 ED utility beds were set up to control ED overcrowding. They tried to manage these high turnover beds, including the admission of ED patients based on a specified order and identifying the cause of the prolonged hospital stay and bed occupation. The outcomes demonstrate that the proper implementation of ED utility beds leads to shortened ED length of stay and the use of 14 high turnover ED utility beds provided earlier admission opportunities (24).

Despite the remarkable increase in ED overcrowding as a national problem, few hospitals have expanded ICU capacity (50). The prediction of the long-term demand for hospital services is difficult (51); moreover, increasing ICU capacity requires a large financial investment in hospital infrastructure and qualified ICU nursing staff (50). Therefore, the most serious problems regarding ED crowding should be considered before making any decisions about increasing ICU capacity, and flexible strategies should be adopted to improve ED overcrowding, as well as ED length of stay and AD. In this regard, hiring hospitalists, merging bed use committees, and enhancing nurse and physician staffing ratios should be regarded as the next program (52).

The role of ambulance diversion band and diversion policy in the reduction of ED crowding

Massachusetts was the first state that banned AD on January 1, 2009 (29, 30). Preliminary reports from this area showed that this was beneficial (53), some other similar collaborative efforts have been initiated to reduce AD in other regions of California (54). The sudden elimination of AD may pose some challenges to numerous EDs, and

a few hospitals objected to AD ban in Massachusetts; however, the gradual process led to decreased resistance of EDs as opposed to AD ban.

Other reports showed successful reduction of AD in the California region by standard ambulance diversions (28). This increase in AD rates in Sacramento in 2001 contributed to some discussions among all stakeholders, and resulted in standardized practices on limited number of ambulance dispatches for each hospital (27).

In this regard, Burke et al. conducted a pre-post observational study to determine changes in ED and EMS timelines after the implementation of the statewide AD ban on January 1, 2009. The decision for the elimination of AD, except for cases of internal hospital disaster, was made due to the success of regional diversion trials (22). Based on the obtained results, a decrease in turnaround time and length of stay for admitted patients was reported in all EDs, except for one of them. The findings indicate that the AD ban did not impose an extra burden on EMS providers.

Another program for AD ban was performed by Asamoah et al. that resulted in increased drop-off times (30). In one study conducted in Boston, the AD ban did not lead to any impact on timelines or crowding (25). Similar findings were reported in San Diego County and Massachusetts (29, 53).

Initially, there was some concern over the concept of an AD ban (55). It was feared that the inability of hospitals to implement the required operational changes to improve patient flow could lead to ED overcrowding and increased EMS turnaround time: nevertheless, the findings of the study by Burke et al. rejected these issues. It is agreed upon that overcrowding is largely due to such output factors as boarding admitted patients in the ED without e-ugh capacity (56-58), while AD is an input factor with a mi-r impact on ED overcrowding (15). This is confirmed by the results reported by Burke et al. since the AD ban had - adverse effect on ED overcrowding.

Formation of improvement teams by housewide initiatives to decrease ambulance diversions

Traditional approaches developed in studies focusing on initial emergency department triage to manage ED overcrowding have had little consequence on AD. Rapid admission policy was used in a study at Stanford University that led to a 10-minute decrease in emergency department length of stay (59).

In this regard, Howell et al., proposed a different approach to emergency department overcrowding which was conducted in Johns Hopkins Bayview Medical Center, a multifaceted intervention, including active bed management and departmental resources performed to assess congestion and flow. As illustrated by the obtained results, a 27% decrease was reported in the AD rate due to the lack of intensive care unit beds in the hospital as the result of emergency department overcrowding (red alert). They pointed out a decrease in AD even in the setting of a higher emergency department census; moreover, the percentages of AD hours due to ED overcrowding (yellow alert) decreased by 6% (32). Although the implementation of the proposed approach imposes a substantial amount of cost to staff active bed management service, increasing the number of inpatient hospital beds costs more. On the other hand, the costs are justified considering the improved efficiency and decreased lost revenue due to AD (17).

Yancer et al. established three teams focused on process improvement, addressing ED admission, patient throughput, and discharge at Shady Grove Adventist Hospital to combat ED overcrowding. The admission team streamlined the hospital admission process to minimize delays in patient transfers to rooms. The patient throughput team identified strategies to enhance patient flow, aiming to mitigate discharge delays and improve care coordination. The discharge team aimed to boost the percentage of discharges before noon, thereby freeing up beds earlier in the day and reducing overcrowding between noon and 6:00 P.M daily. Results demonstrated the effectiveness of these process improvements, evidenced by a decrease in ED overcrowding. Diversion time

plummeted from 2,365 hours in 2003 to 655 hours in 2004, reflecting a substantial 72% reduction in diversion hours. However, an increase in ADs was noted in January-March 2005, correlating with a rise in ED visits. Overall, the integrated performance measures contributed to a reduction in ED overcrowding, decreased length of stay, and an enhanced capacity for patient admissions.(21). All the aforementioned issues help to improve financial performance.

The facilitation of patient transfer from the ED to inpatient care is one of the main challenges in hospitals. The goals of process improvement teams can't be achieved when the clinical and support departments fail to work together as a team; therefore, it is very important to quickly resolve the obstacles. In this regard, tracking the bed turnaround times was very difficult; therefore, they tried to identify the causes of delay in admission from the ED. Finally, a bed tracking system automated the entire process by providing data on each component of the bed turnaround process. This system helps to track turnaround times by unit and staff member and minimize the staffs' delays by identifying areas with the greatest delays (21).

In this context, Watase et al. designed a predivert/full-capacity protocol to control ED overcrowding, consisting of three steps of "predivert" status, assessment of the situation 30 minutes after the an-uncement of step 1, and "full capacity" status. The findings of the referred study indicate a remarkable decrease in the AD rate. The main significance of the protocol developed by Watase is the establishment of clear criteria and phased steps before going on diversion. Predivert/full-capacity protocol focuses on the prediction of ED overcrowding and is cost-effective, compared to other strategies established for the management of ED overcrowding (23). In a similar vein, the effectiveness of the collaborative full-capacity protocol in decreasing LWBS rate and AD despite increased ED volume and hospital admission rates is presented in the study carried out by Willardet al. (33).

The collaboration of local hospitals and emergency medical services agencies

A pre/post study by Castillo et al. (2011) investigated ED diversion in four local emergency medical services agency (LEMSA) regions. The California ED Diversion Project focused on efforts to decrease AD by the collaboration of local hospitals and EMS agencies from September 1, 2007, to June 30, 2008. A number of best practices regarding patient flow initiatives were developed and implemented to improve input, throughput, and output. The information was shared and updates were provided during three separate full-day educational summit meetings at the beginning, midway, and end of the collaboration. Project members in LEMSAs and hospitals were in touch with each other via monthly calls to mentor and develop the best practices. The obtained result of the project indicated that AD is a result of ED and hospital overcrowding (34). They focused on such measures as rapid triage and bedside registration, while other studies targeted hospital capacity issues, including bed tracking systems. During the collaborative year, the participants in California ED Diversion Project tried to implement a number of initiatives to improve input, throughput, and output, as mentioned in the conceptual model of Asplin (42). Although the simplified ED model does not completely reflect the real situation, it can provide the average dynamics of patient flows in ED (60-62).

The nature of California ED Diversion Project was similar to the Urgent Matters Project funded by Robert Wood Johnson, (21) except for its focus on AD, instead of ED overcrowding. Since there is a strong correlation between AD and ED overcrowding (7), and both of them are related to hospital inpatient capacity issues, the approaches and initiatives were similar in both projects. Diversion policies established by local EMS agencies vary from limiting the amount of time a hospital is allowed to go on diversion to completely off diversion, as implemented in Los

Angeles County, Sacramento County, and San Diego County (28, 29).

An oscillatory phemen for AD was reported by two local EDs in California; accordingly, a disproportionate flow of ambulance traffic to a neighboring facility was reported when one hospital went on diversion. Therefore, secured additional resources were provided for one hospital (hospital B) to assess its effect on diversion hours in another hospital (hospital A) during one week. After the intervention, diversion hours decreased from 19.7-1.4 hours at hospital A, while it reduced from 27.7-0 at hospital B. This finding confirmed the reciprocating effects of avoiding diversion of an institution on the neighboring facility (35).

Although the proposed approach is useful, there was some resistance from hospitals and EMS providers against the existing diversion policies of participants in this collaboration. Moreover, the sustainability of these measures depends on the ability to enforce them. In this regard, electronic real-time tracking of EMS data has been suggested by some LEMSAs.

**Determination of optimal patient destination by a destination-control physician**

Shah et al. controlled trial in July 2003 in Rochester, New York, aiming to alleviate ED overcrowding, as measured by hospital AD hours. The study involved the implementation of a destination-control program for patients transported to health centers, with all EMS providers participating. EMS providers communicated brief patient descriptions and suggested destinations via phone calls, enabling destination-control physicians to determine optimal final destinations. While explicit protocols were established for flexibility in response to each situation, general guidelines were outlined for physicians, incorporating EMS providers' and patients' input, along with patient and system characteristics. Results revealed that 69% of eligible patient transports involved voluntary contact between EMS providers and destination-control physicians. Following the intervention, EMS diversion hours decreased by 41% and 61% at the university hospital and community hospital compared to the control month. The program facilitates destination changes during hospital overcrowding, potentially mitigating congestion and pressures near EMS. Understanding hospital capabilities, patient needs, and ensuring continuity of patient care are crucial aspects for optimizing the quality of healthcare delivery in this context (36).

In the same context, McLeod et al. used a program for proactive destination selection, aiming to improve capacity and streamline ED flow management. They introduced a dashboard synthesizing real-time capacity and acuity data. The results indicated a simultaneous reduction in EMS avoidance, decreasing from 4.4% in the pre-intervention period to 1.8% post-intervention(20). Achieving equilibrium between supply and capacity to enhance dispatch optimization, while taking into account various pertinent factors of the patient load, is a key feature of the system proposed by McLeod et al. Sustained reduction in AD is seemingly achieved by alterations in internal hospital processes. In a similar study conducted in Rochester, eight emergency physicians took charge of dispatch assignment by integrating the information obtained by EMS at the scene with ED overcrowding information (36). Nevertheless, Rochester Program places emphasis on the advanced education and training of its personnel, whereas the system proposed by McLeod et al. relies on pre-established triggers within an automated system for the determination of EMS routing.

Ambulance Destination Determination Systems, which were developed in other regions, such as Edmonton and Perth(63). The systems highlight the importance of focusing on the prevention of overcrowding which is implemented using a dispatch system before overcrowding leads to AD and increased EMS offload times.

**Conclusion**

In summary, increasing bed capacity, AD ban and diversion policy, the formation of improvement

teams, the cooperation between regional hospitals and emergency medical services organizations, and determination of optimal patient destination by a destination-control physician are the main strategies for decreasing ambulance deviation in order to reduce ED overcrowding. Based on the obtained evidence, the provision of solutions to back-end problems would bring about the best outcomes. Some studies strived to develop an ACU as a new form of controlling patient flow at the back-end of ED, while other studies tried to control ED overcrowding by increasing bed capacity. Expanding ICU capacity necessitates a substantial financial commitment to hospital infrastructure, along with covering the expenses associated with employing adequately trained ICU nurses. Although the effectiveness of the AD ban and --diversion policy in decreasing EDO is confirmed, since an increase in ED inflows has been predicted, the finding may be affected by greater ED outflow; consequently, the improved ED overcrowding leads to collaborative endeavors by healthcare institutions to implement the necessary operational modifications. Therefore, a combination of ED output factors (hospital-wide operational changes) and ED inputs (ambulance volume) should be considered to determine the contribution of each of them. The goals of process improvement teams can't be achieved when collaboration between clinical and support departments falters; therefore, it is very important to quickly resolve the obstacles. The process should be integrated with an automated bed tracking system to provide information pertaining to every aspect of the bed turnaround procedure. The cooperation between regional hospitals and emergency medical services organizations is the other strategy to decrease AD in order to reduce ED overcrowding; the project may face resistance from hospitals and EMS providers. Moreover, the sustainability of these measures widely depends on the ability to enforce them. The other introduced strategy is the determination of optimal patient destination by a destination-control physician. In conclusion, a multilevel approach in combination with increasing inpatient bed capacity should be considered for the management of ED overcrowding. Pressure on ED may increase in the future, and the effectiveness of changes in hospital policies and ED procedures should be considered instead of increasing hospital bed capacity. It is suggested that future studies focus on these issues.

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**Ethical Consideration:**

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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## Tables& Figures

**Figure 1. PRISMA flow chart representing the process of paper selection in the rev**

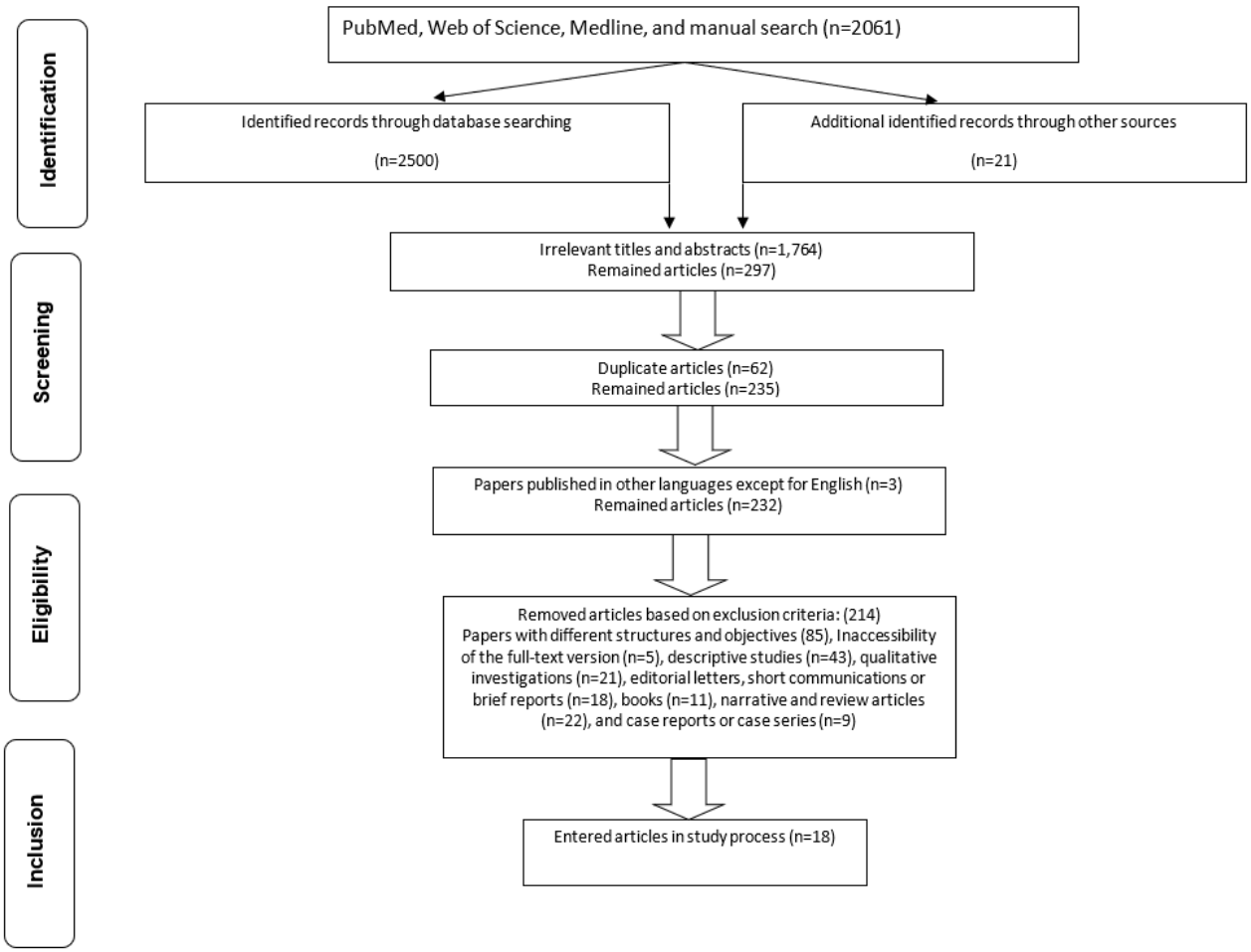

**Figure 2. Quality assessment of entered studies in the review**

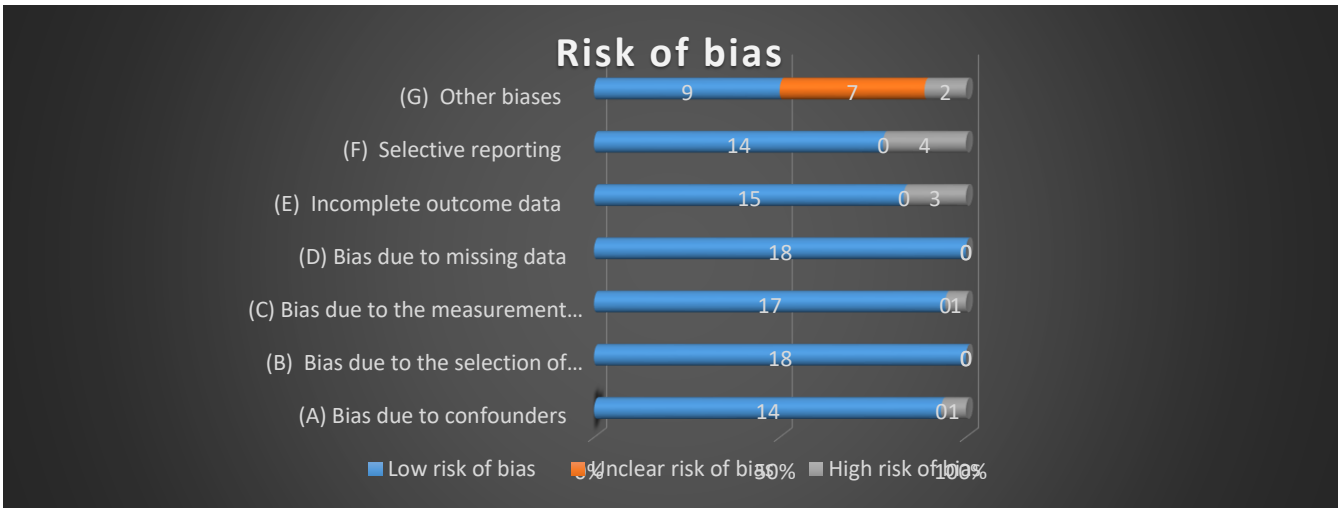


**Table 1. Extracted data from the included studies**

| Authors | Country | Type of study | Sample | Duration | Waiting Time | Ambulance diversion time | Intervention | Outcome |
|---|---|---|---|---|---|---|---|---|
| Kelen et al. (2004) (26) | Maryland, USA | Retrospective observational study | 1,589 patients | One year | 40% reduction in the LWBS[1] | Decreased from 6.7 h per 100 patients to 2.8 h per 100 patients after the unit opened | A bed acute care unit recently opened remote from the main ED | An ED-managed acute care unit can have an impact on ED overcrowding and AD[2] |
| Vilke et al. (2004) (29) | California, USA | Prospective before-after intervention | 235,766 patients were transported to an ED | Two year | -- | Decrease in monthly hours on diversion for the trial period (4,007 versus 1,774) (73%) | Standardized diversion guidelines (A voluntary community-wide approach) | Reducing hospital ED diversion by a voluntary community-wide approach. EDs overcrowding above baseline was |

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| | | | | | | | | not reported during the study period. |
| Vilke et al. (2004) (35) | California, USA | Prospective before-after intervention | Two neighboring urban teaching EDs with a census of 45,000 and 39,000, respectively | Three weeks | -- | Hospital A: 19.6 versus 1.4 hours Hospital B: 27.6 versus 0 | A tiered response system based on dispatch criteria: Avoid diversion status by one hospital to avert in the neighboring facility. | Frequency of AD decreased when nearby hospitals stopped diverting ambulances. |
| McConnell et al (2005) (19) | Portland, Oregon, USA | Retrospective pre-post-study | One hospital (42,000 visits) | Two years | LOS[6] for admission decreased from 523-454 | AD decreased from 3.8 hours to 1.4 hours (66%). | The number of ICU beds increased from 47 to 67 | Increasing the capacity of ED beds leads to a decrease in length of stay and AD |
| Patel et al. (2006) (28) | Sacramento, California, USA | Retrospective pre-post-study | 17 hospitals (608228 patients in 2001 to 648007 patients in 2003) | Three years | -- | 23785 hours of AD in 2001 and 7143 in 2003 A 74% decrease in AD hours | An internet-based AD monitoring and tracking program considering real-time monitoring of the AD status. | Community-wide diversion policy decreased diversion hours by 74%, despite a 6.5% increase in the census and 8.8% in admissions. |

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| Shah et al. (2006) (36) | **Rochester**, New York, USA | Prospective before-after intervention | A university hospital and a university-affiliated community hospital (2,708 patients) | Two months | -- | A decreased by 41% in EMS[3] diversion hours at the university hospital and 62 (61%) hours at the community hospital than the control month. | Determination of optimal patient destination by a destination-control physician considering patient and system variables as well as EMS providers' and patients' input. | Destination-control program reduced diversion hours by 41% at a university hospital and 61% at a community Hospital. |
| Yancer et al. (2006) (21) | Maryland, USA | Prospective before-after intervention | One hospital | One year | Reduction in ED average LOS for admitted patients by 25 minutes. | Decrease of AD hours from 2,365 to 655 (72%) | Three process improvement teams, including discharge team, patient throughput team, and ED admission team | Three process improvement teams considering a holistic approach to identifying and removing throughput barriers leads to reductions in ADs and ED overcrowding |
| Asamoah et al. (2008) (30) | USA | Retrospective pre-post study | 600 000 people and 10 hospitals | September 2004 to February 2006 | The average percent time closed decreased | Diversion hours decreased to 18% | Restricting diversion hours to 1 hour out of every 8 | - significant difference reported in the number of |

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|---|---|---|---|---|---|---|---|---|
| | | | | | from 4.7% to 0.8% | | | monthly transports<br><br>A decrease in monthly AD hours and an increase in additional time required to transport patients |
| Howell et al.<br><br>(2008)<br><br>(32) | Maryland, USA | Prospective before-after intervention | Johns Hopkins Bay view Medical Center<br><br>(54 607 visits) | -vember 2006 to February 2007 | – | Decrease in the rate AD due to lack of intensive care unit beds in the hospital because of emergency department crowding: 27%<br>(Decrease in percentages of AD hours 6%. | Active bed management and quality improvement initiative | Active bed management and quality improvement initiative leads to a significant decrease in AD |
| McLeod et al.<br><br>(2010)<br><br>(20) | Alberta, Canada | Prospective before-after intervention | Three EDs<br><br>(103,745 visits) | One year | Length of stay decreased from 15.02 to 11.78 hours | Decreased from 198 to 27 hours | REPAC[4] program | Increase in regional capacity and flow management with a decrease in AD after using proactive EMS destination |

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| | | | | | | | | selection system |
| Friedman et al. (2009) (25) | Boston, Massachusetts, USA | Retrospective pre-post-study | Nine hospitals and the municipal EMS | Two weeks | LOS for admitted patients decreased (median differences= 0.30 hours; P=0.03) | not reported | - diversion trial | The length of stay for all patients and the number of daily admissions were significantly decreased. The majority of EMS respondents agreed to - diversion policy |
| Castillo et al. (2011) (34) | California, USA | Prospective before-after intervention | 31,735 diversion hours | September 1, 2006, to August 31, 2008 | -- | Pre:1468 min Post: 1176 min difference of 292 h; 95% confidence interval 99-484; P=0.007 Diversion hours decreased by19.9%. | CEDDP[5] by the collaboration of local EMS agencies (Three separate full-day educational summit meetings, in the beginning, midway through the project, and at the conclusion of the | Ongoing collaboration of local EMS agencies helps to decrease AD |

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| | | | | | | | collaborative ) | |
| Watase et al. (2012) (23) | Portland, USA | Retrospective pre-post-study | One hospital (43 000 annual visits) | 12 months | LWB decreased from3.1 to 1.4 LOS decreased from 4.1 to 3.7 | Decreased diversion rate after the intervention (odds ratio, 0.32; 95% confidence interval, 0.21-0.48). | Predivert/full-capacity protocol with education physicians and charge nurses | Predivert/full-capacity protocol leads to a significant decrease in the AD rate. |
| Patel et al. (2012) (27) | California, USA | Prospective before-after intervention | 17 hospitals | 2006-2009 | | Decreased from 8469 h in pre-implementation to 4592 h during implementation (87.4%) | Reduce and eliminate AD by the progressive reduction of the duration of each AD event (re-open a hospital to ambulance traffic) | AD decreased by limiting the duration of AD events to progressively shorter periods of time using a region-wide, Internet-based EMS program. |
| Burke et al. (2013) (22) | Mass | Retrospective pre-post-study | 9 EDs Population (723,000) | Two years | A 10.4-minute decrease in LOS | A 2.2-minute decrease in turnaround time | Statewide AD ban | - increase in ED length of stay or ambulance turnaround time observed after the first statewide AD ban |

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| Lee et al (2017) (24) | Taiwan | Retrospective, observational before-and-after study | One hospital (70,515 adult ED visits) | July 2012–June 2013 | Length of stay decreased from 9.7-8.0 h. | Reduced from 5.4-1.6 h per day. | Increasing capacity by preparing 14 utility beds exclusively for ED patient use and considering a strict 48-hour course limit for each patient | ED overcrowding output decreased by the high turnover ED utility bed intervention. |
| Willard et al. (2017) (33) | Kansas, USA | Retrospective pre post-study | One hospital (50,000 annual visits.) | 5 months | Decrease 10.2%decrease in LWBS rate increase in LOS of 34 minutes | A 92% decrease in AD hours was reported | a full-capacity protocol is based on collaboration among multiple hospital units | Effectiveness of the collaborative full-capacity protocol in decreasing patient left without being seen and AD despite an increase in ED volume and increased hospital admission rates |

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| Rogers et al (2019) (31) | -rthern Arizona, USA | Prospective before-after intervention | Six hospitals | A 20-week trial | -- | AD fell from 13.10-2.23 h per week | AD protocol applying the protocol used by the National Emergency Department Overcrowding Scale tool, with corresponding overcrowding response strategies to make AD decisions | AD was decreased successfully using the AD protocol |

1- Left Without Being Seen, Emergency, 2- Ambulance Diversion, 3- Emergency Medical Services, 4- Regional Emergency Patient Access And Coordination, 5- California Emergency Department Diversion Project, 6- Length Of Stay

## Table 2. Quality assessment of entered studies in the review

| Authors | Bias due to confounders | Bias due to the selection of participants | Bias due to the measurement of intervention | Bias due to missing data | Incomplete outcome data | Free of selective reporting | Other sources of bias |
|---|---|---|---|---|---|---|---|
| Kelen et al. (26) | + | - | - | - | + | + | + |
| Vilke et al. (29) | - | - | - | - | - | + | - |
| Vilke et al. (35) | - | - | + | - | + | - | - |
| McConnell et al. (19) | - | - | - | - | - | - | + |
| Patel et al. (28) | - | - | - | - | - | + | Unclear |
| Shah et al. (36) | - | - | - | - | - | + | - |
| Yancer et al. (21) | + | - | - | - | + | - | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Asamoah et al.(30) | - | - | - | - | - | - | Unclear |
| Howell et al. (32) | - | - | - | - | - | + | - |
| McLeod et al.(20) | - | - | - | - | - | + | - |
| Friedman et al. (25) | - | - | - | - | - | + | Unclear |
| Castillo et al. (34) | - | - | - | - | - | + | Unclear |
| Watase et al. (23) | + | - | - | - | - | + | Unclear |
| Patel et al. (27) | - | - | - | - | - | + | - |
| Burke et al. (22) | - | - | - | - | - | + | - |
| Lee et al. (24) | - | - | - | - | - | + | Unclear |
| Willard et al. (33) | - | - | - | - | - | + | - |
| Rogers et al. (31) | + | - | - | - | - | - | Unclear |