BMJ Open Quality

Efficiency measures of emergency departments: an Italian systematic literature review

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To cite: Di Laura D, D'Angiolella L, Mantovani L, *et al*. Efficiency measures of emergency departments: an Italian systematic literature review. *BMJ Open Quality* 2021;**10**:e001058. doi:10.1136/bmjoq-2020-001058

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bmjoq-2020-001058).

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Received 13 June 2020
Accepted 16 August 2021

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ABSTRACT

Life expectancy globally increased in the last decades: the number of people aged 65 or older is consequently projected to grow, and healthcare demand will increase as well. In the recent years, the number of patients visiting the hospital emergency departments (EDs) rocked in almost all countries of the world. These departments are crucial in all healthcare systems and play a critical role in providing an efficient assistance to all patients. A systematic literature review covering PubMed, Scopus and the Cochrane Library was performed from 2009 to 2019. Of the 718 references found in the literature research, more than 25 studies were included in the current review. Different predictors were associated with the quality of EDs care, which may help to define and implement preventive strategies in the near future. There is no harmonisation in efficiency measurements reflecting the performance in the ED setting. The identification of consistent measures of efficiency is crucial to build an evidence base for future initiatives. The aim of this study is to review the literature on the problems encountered in the efficiency of EDs around the world in order to identify an organisational model or guidelines that can be implemented in EDs to fill inefficiencies and ensure access optimal treatment both in terms of resources and timing. This review will support policy makers to improve the quality of health facilities, and, consequently of the entire healthcare systems.

INTRODUCTION

Worldwide, in the last 150 years, human life expectancy has rapidly increased, doubling from around 45 years to 80 years, in many industrialised countries. Driven by increases in life expectancy, the world's population is ageing, and this growth is projected to accelerate in the coming decades. The number of people aged 65 or older, accounts for 21% of the global population; however, over the next 30 years, the number of older persons is projected to increase to 33%, in 2050 (WHO, ISTAT Geodemo—2017). These extra years of life and demographic shifts have profound implications for health systems and the societies in general, since ageing is a well-established risk factor also for the development of several multiple chronic diseases, including cardiovascular disease, stroke, cancer, osteoarticular and neurological diseases. The exponential increase of chronical disease due to the ageing world population leaded consequently to increase of healthcare demand. Older people generally have more complex problems, requiring more investigations, admissions and critical care. It is also worth noting that elderly patients have considerable comorbidities, seem increasingly to be sent to emergency departments (EDs). In the recent years, the number of patients visiting the hospital EDs rocked in almost all countries of the world. These departments are crucial in all healthcare systems and play a critical role in providing an efficient assistance to all patients, especially for elderly with chronic and multichronic conditions. Inefficiency EDs are an ongoing issue for hospital staff, healthcare administrators, policy makers and patients. With increasing patient demands on these services and constricting budgets, administrators are in search of practical and implementable solutions to optimise patient flow and increase throughput.[1]

Over the last decades, the role of EDs has evolved and EDs have become providers of not only acute emergency services, but also of care for patients needing in general, of primary healthcare,[2] trying always to provide an efficient and quality service to all patients.[3]

The increase in our ageing population presents many opportunities and several public health challenges that we need to prepare for. The most important challenge for healthcare systems is to provide assistance, improving efficiency, productivity, and the appropriateness and quality of care and its departments and for this aim, various tools and approaches have been proposed in the literature so far in different healthcare settings and for different objectives aimed at improving the quality of the provided services.[4–9] However, no objective and officially parameters that can assess the true efficiency and quality of these EDs

were recognised. This study aims to review the literature on the issues encountered in the efficiency of EDs worldwide.

METHODS

The review of the literature, following Sashi *et al*[10] methodology, adopts three steps as summarised below:

1. Papers selection:
   - A selected set of keywords was used to find the articles.
   - A definition of the inclusion/exclusion criteria was carried out in the selected articles.
2. Descriptive analysis:
   - A descriptive analysis and classification of the articles was developed on the selected articles.
3. Theoretical and content analysis of the selected papers:
   - A theoretical and content analysis was described in the articles selected according to their theoretical reference model.

Additionally, citation and cocitation analyses have been conducted to identify historiography results, clusters of main contributions and authors in the field, as well as analysis of clusters. Finally, all contributions have been divided into thematic areas to have a complete overview on the subject.

Papers selection

A systematic literature review was conducted to describe and analyse the world's EDs in order to select efficiency measures of EDs. Searches of three electronic database (PubMed, Scopus and Cochrane Library) were performed from 2009 to 2019, using the following keywords: 'emergency' AND 'department' AND 'efficiency'.

To be included in the present review, articles were required to fulfil the following criteria:

The inclusion criteria were as follows: original research (ie, clinical study, clinical trial, comparative study, observational study) regarding the efficiency of EDs for human admitted patients, published in the last 10 years and written in English or Italian.

The exclusion criteria were as follows: systematic reviews previously published; abstracts, poster presentations, case reports, letters, comments, editorials, and review papers (not published as full papers), studies not quoting outcome in the result section and studies related to specific diseases and departments or specific subgroup of patient.

Descriptive analysis

For each included study, we extracted the following data using a standardised form: author and year of publication, country of study, aim and design, study setting, data source, number of included patients and year of data collection, intervention, type of outcome, results, limitation and conclusion.

The title and abstract of primary results were examined and potentially relevant articles were reviewed in full text, and only articles that fulfilled the inclusion criteria were considered for final appraisal.

Theoretical and content analysis of the selected papers

References were checked automatically and manually to identify and remove duplicates.

Titles and abstracts were examined by three members of the review team (DDL, GS, FC). Disagreement between the three reviewers was resolved by consensus of a third party (LSD).

Potentially relevant articles were reviewed in full text, and only articles that fulfilled the inclusion criteria were considered for final appraisal.

RESULTS

The literature search of the selected databases yielded 718 references. Fifty-four redundant papers were removed using the auto-searched method, and the remaining articles (664 papers) were screened. Starting from the titles, 251 articles were excluded. The remaining 413 articles were analysed reading the abstract and 344 were excluded. Among the 69 selected full text, 28 studies were included in the current review. The selection process through the different phases of the review is depicted in figure 1.

Of the 28 articles analysed: 9 were conducted in the USA, 6 in Australia, 3 in Canada, 2 in China, 2 in France, 1 in Italy, 1 in Portugal, 1 in Sweden, 1 in the Netherlands, 1 in Germany and 1 in UK. Figure 2, over the period of systematic literature review (January 2010–2019), showed an increase in the number of published papers, on hospital EDs. The number of published papers increased from 2 in 2010 to 11 papers in 2018 in first month of 2019. The greatest increase in the number of published papers was reported from 2014 (figure 2).

Among the 28 studies, 12 aimed to evaluate the impact of resources implementation, 9 to evaluate already existing resources, 5 to describe models or simulations and 4 to compare performance measures over levels of urgency, between two or more hospitals. Overall, 75% of included studies were retrospective or prospective observational, 18% were modelling studies, 7% was designed as quasiexperimental study and pragmatic cluster randomised trial.

The quasiexperimental study was conducted with an uncontrolled, interrupted time series analysis, since the random allocation was not feasible, to investigate the impact of national healthcare reforms on ED time-based process outcomes. The randomised-controlled trial performed from Cheng *et al* assessed the impact of a physician (MD)–nurse (RN) supplementary team at triage (MDRNSTAT) on ED. During the study, patients were randomly assigned to intervention or the control group, using a computer-generated algorithm.

Concerning research setting, we classified hospital EDs according to the number of visits per patient per year or availability of hospital beds. Thirteen studies were performed in hospitals with <70 000 ED patients/year, seven in hospital with 70 000–100 000 ED patients/year

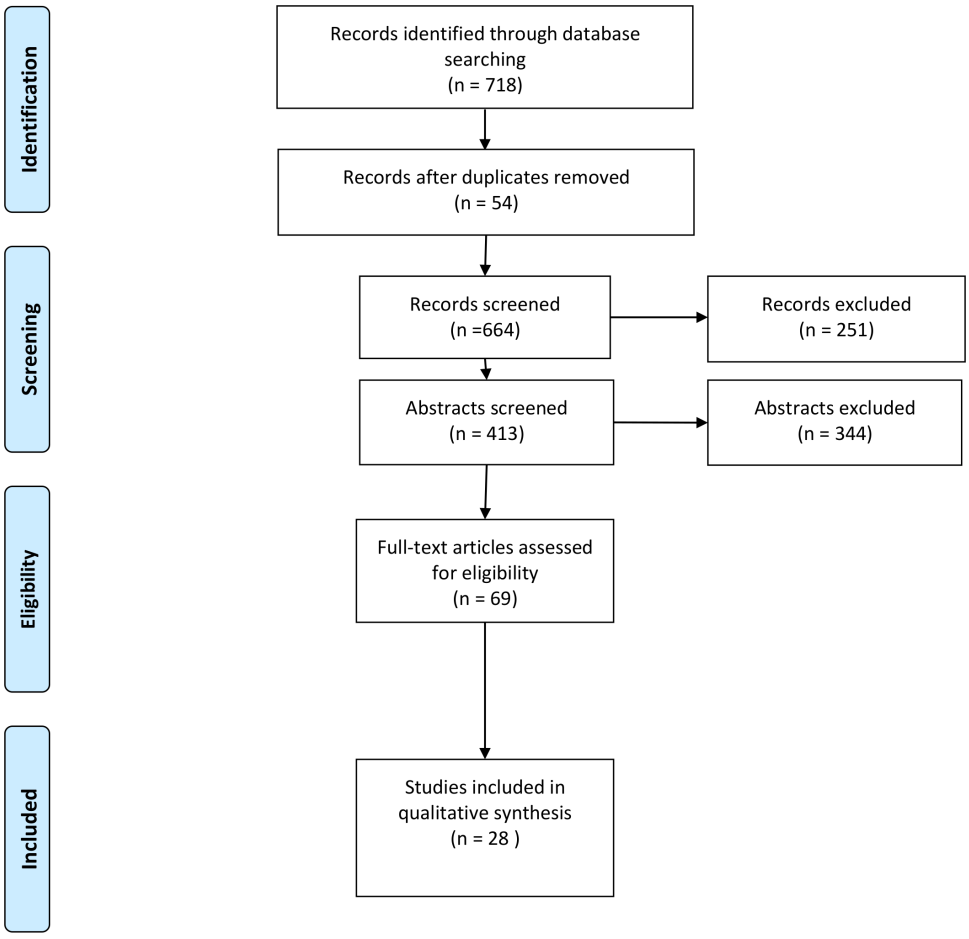

Figure 1 PRISMA 2009 flow Diagram. Adapted from Moher *et al*[44].

and six studies were about hospital with more than 100 000 ED patients/year. The number of ED patients/year ranged from a minimum of 28 000 to a maximum of >300 000. Two studies provided information on hospital capacities only in terms of bed numbers, reporting 74 and 495 beds as study settings, respectively. The most frequent types of data source were electronic medical records systems (68%), administrative databases (25%), in-hospital physician contacts and real world data from clinical practice (7%).

The patient sample size in the modelling analysis ranged from 30 to 33 710, except for one study that did not report the number of simulated patients.

The observational studies included in this review varied in sample with a minimum of 599 to a maximum of 5.8 million patients, excluding one study with missing

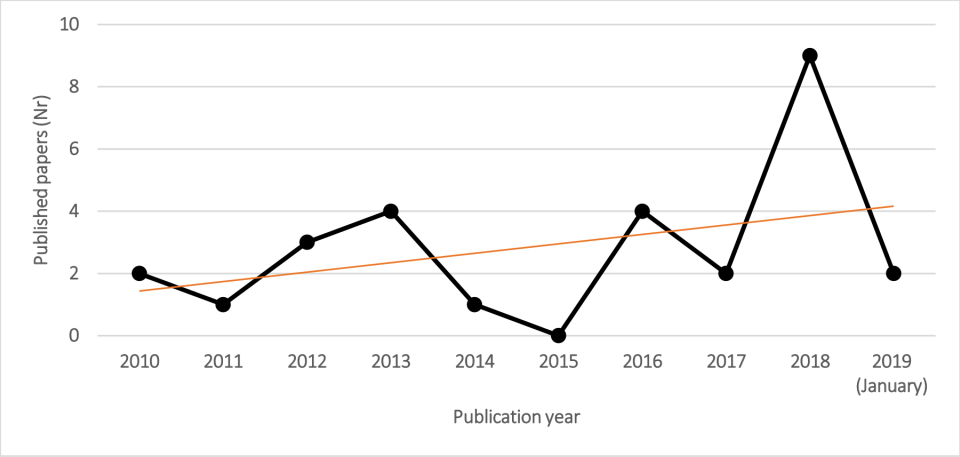

Figure 2 Number of selected papers over publication years.

information. Over the 11-year period 2006–2016, the quasiexperimental study reported 13 241 509 ED presentations in 34 Victorian hospitals. The study conducted by Cheng *et al* randomised 3137 patients to intervention group and 3163 to control group.[11] Other details on characteristics of included studies were summarised in online supplemental table 1.

Efficiency measures

Overall, the studies showed mixed performance measures associated with the quality of ED care. The most frequently used measures of ED efficiency: length of stay (LOS), process waiting times, indirect quality indicators in order to evaluate the impact of overcrowding or resource allocation (ie, Left Before Visit Complete (LBVC), left without being seen (LWBS), left without being seen by a physician (LWSP) or performance in the EDs (number of visits or patient admitted) and mortality.

Length of stay

LOS has been suggested as a quality measure in 15 of 28 studies (53.6%) and it was generally defined as the difference between ED arrival and the time that the patient left the ED for discharge or admission. LOS was recognised as an outcome of efficiency measure and a useful tool to evaluate ED processes, performance and quality of care in older and more recent studies .[12 13] Long LOS in ED could represent the stress of overburdened healthcare systems. Efficient and effective patient flow in the ED could be quality outcomes as well as patient safety and satisfaction and care optimisation.[14] The results of the studies agreed that reduced LOS resulted in greater patient satisfaction in patients with mild and serious illnesses seen in ED's who needed immediate treatments or fast assistance flow.[15] All included studies except one[16] have demonstrated significant reductions in patient LOS after implementation of interventions to improve ED department performance; however, key differences exist as well, concerning study setting, differences existing in ED patient populations, intervention, hospitals structure and setup (eg, public or private funding, tertiary or non-tertiary). Studies agreed that skilled, timely care[17 18] is crucial.[19] The largest magnitude of improvement in ED performance was reported from McHugh *et al*,[20] who evaluated the impact on LOS of the ED Telehealth Express Care Service: a combination of new technology, informed consumers, patient-centred care based on a 'virtual visit' with a board-certified emergency medicine attending physician located remotely, in the USA. One thousand and three hundred patients who present to the ED with minor complaints after triage and medical screening evaluation have been treated with care service and experienced decreased LOS leading to an overall 24% decrease in ED LOS (2.5 hours to 38 min) and increased satisfaction. Less recently, Baumlin *et al*[21] redesigned the patient work flow in a tertiary academic with a separate department of emergency medicine hospital of New York City: a fully integrated ED information system with patient tracking computerised charting and order entry. This process expedites rapid triage and allows orders to be entered and carried out within minutes of patient arrival. The ED LOS for all patients decreased by 29%, from 6.69 hours pre intervention to 4.75 hours post intervention, patient satisfaction has improved as well. Strom Verloost *et al* compared LOS[16] over levels of urgency before and after the implementation of the Manchester Triage System (MTS), based on a flowchart with five triage categories according to level of urgency and waiting time, in Netherlands University teaching hospital. Regardless of the effectiveness of the implementation of the MTS, the authors associated the LOS and waiting times to efficiency and quality of EDs.

Time intervals

Door to provider, to order time, to disposition and to physician were identified as other significant study outcomes. Li *et al*[22] defined door-to-order time and door-to-disposition time as the time interval between patient registration and the prescription of the first order by the EP or the completion of patient disposition by the EP, respectively. Other studies[13 23] calculated the door-to-doctor time as mean time to see a physician, from patient registration to documented time of physician encounter for all patients. Welch and Dalto[24] defined the door-to-doctor time as the time interval between when a patient was recognised as an ED encounter and physically present in the department to the time when a physician entered the patient care room. Baumlin *et al* defined door to doctor time as triage time to the time the attending physician signed up for the patient.[21] In these studies, selected outcomes were used to evaluate EP efficiency and important criteria for bench marking ED operational performance and a quality measure for the ED.[24] They were correlated with patient satisfaction and clinical quality.[22–24] Interest for these outcomes has recently increased and officially recognised.[25]

Wiler *et al*, conducted a retrospective observational pre–post intervention comparison study and described the development and the implementation of a novel process design in a large academy urban ED with 75 000 ED annual visit, in the USA. It was a split flow model consisted of deployment of a novel intake model, implementation of a 16 bed clinic decision unit, expanded point of care testing and dedicated ED transportation services. During the 6 months pre and post implementation periods, these processes resulted in: a 30 min decrease in door-to-physician time (from 54 to 15 min), a 45 min decrease in LOS (from 220 to 175 min) and improved patient satisfaction by 7% (average score 77.9 vs 83.4). The authors showed that the improvement in door-to-physician time was strongly correlate with LOS improvement, patient satisfaction, as well as to correlate with quality and safety outcomes (Boudreaux *et al*[26]). Recently, around the world 'the 4-hour target' has been proposed as a new measure of the ED performance. More exactly, it is the as the percentage of admitted

patients that had spent less than 4 hour in the ED or that were treated and discharged (to home or to ward) within 4 hours.[27–31]

In Sweden, Muntlin *et al* announced that visiting times in the ED had to be shortened, for quality and safety reasons and reported that the performance target had to be met for 80% and 100%, by the end of the first 6 month and 1-year period, respectively.[30]

The other two papers included in this review reported the percentage of presenting patients that left the ED within 4 hour as National Emergency Access Target (NEAT).[27 28] The studies were conducted in Australia: Woodward *et al* studied multiple models of care in an effort to improve different performance indicators of ED, including total number of ED presentations; number of admissions by specialty; and NEAT performance; total ambulance ramping time; total in-hospital mortality; ED 30 day representations; number of patients who did not wait to be seen.[27]

Khanna *et al* identified optimal inpatient discharge time targets to help hospitals reduce crowding, improve patient flow through the ED and balance staff workload[28] Casalino *et al*[31] in France determined the association between ED quality and input, throughput and output associated variables. The authors determined the daily percentage of patients leaving the ED in <4 hours as ED quality and performance indicator, in 1-year prospective observational cohort study. The results of this study indicated that the daily percentage of patients leaving the ED in <4 hours is associated with ED operating characteristics measuring input to the ED, ED and hospital variables measuring throughput and ED and hospital dependent variables measuring output. In this study, it is a useful tool to evaluate nursing teams performance in the process of care, and it probably reflects the work dynamics of all nursing teams.

Left without being seen

The percentage of patients leaving the ED without being seen by a doctor (LWBS) was considered an indicator of ED efficiency in eight articles, independently of the duration of the study. Duration of studies ranged from 16 days[32] to 3 years.[29] The studies evaluated: introduction of a team of doctors with specific training in emergency medicine working full time in the ED,[33] the addition of a physician assistant acting as a triage liason providers,[32] the addition of a physician–nurse supplementary triage assistance team,[11] the redesigned of the ED operational nursing leadership,[29] the impact of a multifaceted ED work flow redesign,[23] the application of Lean principles of the Toyota production system[13] and three reliability tools and strategies,[24] the impact of nine flow designed models obtained by the combination of three ED flow models a three ED physical design typologies.[12]

Ninety per cent of the studies showed an improvement of LWBS rate. The value is correlated with patient care[29] and medical attention [Ding *et al*[34]; Baker[35]].

Wiler *et al*'s study is the only study that has calculated besides LWBS, also the outcome LBVC defined as the percentage of patients left before visit complete.[23]

Only Ramos and Paiva, which evaluated the pre and post period after the introduction of a team of doctors with specific training in emergency medicine working full time in the ED, did not present the same trend of improvement, proving an initial worsening of LWBS rate. According to the author, this result is probably due to the introduction of a new triage system in the same time of the study 'which may have led to an increase in dropouts in the less severe visits, which account for a high share of the ED's volume [CRRNEU[36]; Martins[37]]

Mortality

Mortality was considered as an ED quality measure in four articles.[11 22 33 38] In a pre–post design study, Ramos and Paiva[33] compared two different organisational models of delivering emergency care in the same hospital: the first one in 2002 with doctors from various departments taking turns in the ED, and the second one in 2005–2006 with a dedicated team with specific emergency competences. The overall mortality rate was 0.4% in 2002, 0.6% in 2005 due to an influenza epidemic in Portugal and 0.5% in 2006. The study notices no relevant improvement of the mortality rate before and after the new model.

Claret *et al*[38] in France conducted a before–after study analysing as a primary outcome the inpatient all-cause mortality rate of all patients admitted from ED before and after a new ED organisation and segmentation structure. In the before period, the overall mortality rate was 1.5% during winter 2011, 1.5% during summer 2011, 1.8% during winter 2012, while after the new ED layout, the mortality rate decreased to 1.3% during summer 2012.

The study shows that the mortality rate decrease was related to LOS and first medical contact (FMC) time reduction, and it reinforces the idea that the restructuring of ED has led to an improvement in patient's outcome.

In a retrospective 1-year cohort study conducted in three different EDs in Taiwan, Li *et al*[22] used mortality rate as an outcome to evaluate quality of care related to emergency physicians seniority. Mortality rate was defined as the number of deaths within the ED divided by the total number of ED patients. EPs were divided into three groups according to the seniority and the study showed a lower mortality rate of 0.02% in the senior EPs group than did the other two groups with a rate of 0.1% among non-urgent patients. After adjusting for patient's age, sex, disease acuity and medical setting, the junior and intermediate EPs showed higher patient ED mortality rates than did the senior EPs (aOR ¼1.5, 95% CI: 1.02 to 2.20 and aOR ¼1.6, 95% CI: 1.04 to 2.43, respectively). A lower rate was observed among urgent patients with 2.9% for the senior group and respectively 4.3% and 4.5% for the other two groups. This finding indicates that the lower ED patient mortality rate that was observed among patients treated by the senior EPs might have been related to the

clinical experience of these EPs and less related to an ED efficiency criteria.

Over a 26-week period, Cheng *et al*[11] conducted a cluster, randomised-control trial evaluating the impact of a physician–nurse supplementary triage: one of the secondary outcomes observed was a 7-day mortality rate of 0.16% in the control group, 0.8% in the EP group, 0% in MDRNSTAT group and 0.06% in the combined group (EP +MDRNSTAT).

However, this study was not powered to detect mortality differences.

Waiting times

In studies where the waiting time was evaluated, different definitions were reported.[7 11 16 17 30 31 39] The majority of included studies reported waiting times over levels of urgency, based on triage system for each ED.[7 11 16 17 39] Waiting time to treatment was defined as, the time between a patient's arrival at the ED or the commencement of their clinical care and measured in minutes.[17] However, all studies evaluated the waiting time as a performance indicator of the EDs. Improta *et al* evaluated the efficacy of a lean thinking on ED, in Italy. The authors chose parameters, as ED performance measurements, primarily related to waiting times and service delivery depending on the triage colour code.[11] They evaluated the time from the patient's arrival at the ER until the patient leaves the ER. The authors reported, according to colour codes: the percentage of patients with green code not hospitalised with stay times ≤4 hour or examined within 1 hour, the percentage of patients sent to hospitalisation with stay times ≤8 hour, and percentage of patients with a yellow code examined within 30 min. Prang *et al*[17] evaluated the waiting time to treatment, in different types of ED (major/large/medium/small hospitals), pre and post the application of government national healthcare reforms. The outcomes were observed across five triage categories and hospital peer groups. Waiting time to treatment was defined as the time elapsed between triage and the commencement of assessment and treatment. In another study conducted in Australia, the length of time patients wait to be treated after presenting at an ED was routinely used to measure ED performance, according to triage categories.[38] In Netherland, Storm-Versloot *et al* compared waiting time, according to new MTS. The authors also identified five levels of urgency (red, orange, yellow, green and blue) with different timing of care, ranging from immediately to 4 hour).[16] Casalino *et al*[31] evaluated different time interval metrics as ED quality and performance indicator and determined the daily percentage of patients in the ED in <4 hours.

Other efficiency outcomes

Other outcomes of interest in selected papers were access block[27 40] (ED LOS longer than 8 hours for an admitted patient), ambulance ramping[27] and the delay to FMC.[20] These outcomes were recognised as indicators of overcrowding. ED occupancy rate,[28 40] readmission rate[22] (patients who returned to the ED within the 72 hours after discharge), discharge rate[22 33] (patients discharged home after being attended to in the ED divided by the total number of ED patients) and the bed utilisation rate[11] (patients seen in an ED room in 24 hours) were served as an index of ED operational measures and quality indicators.[33]

The number of patient movements (number of movements a patient makes between ED locations of either waiting area or treatment space) was included as a balancing measure to account for patients' desire for resources to come to them rather than moving repeatedly, from Easter *et al*.[12] Other papers reported outcomes that reflected a patient's access to care. They were the level three escalation (patient on stretcher time greater than 30 min),[27] the elapsed time between when the patient is ready to move to when the patient physically occupies a clean bed,[41] waiting time to treatment or test,[11 16 21] treatment within recommended time.[17]

Less frequently, other patient related outcomes have been studied, that is, satisfaction (patient) score[13 20 42] and ED productivity and costs.[33]

DISCUSSION

Overcrowding at the ED has become a serious problem in public health. The causes of overcrowding in EDs are multiple and intertwined. Increased delays in care have a major impact on ED flow.[41 43] To analyse this issue, important variables, recognised as indicators of overcrowding, must be analyse to understand how to improve outcomes for ED patients.[21 27]

Indicators measure of the performance of the ED could support managing patients and decisions process. Time intervals measuring the work dynamics of medical and nursing teams are particularly important in measuring overall ED functioning.[30]

The LOS of the ED, door to provider and LWBS rate were the most common outcomes for measuring the EDs efficiency. Others outcomes applied for measuring efficiency were waiting time to assessment and discharge rates. Some studies showed how it is possible to make the ED more efficient through better management of the patient's stay time. The length of time patients wait to be treated after presenting at an ED is routinely used to measure ED performance; however, triage waiting times need to take into account the mix of patients and the mix of hospitals. Waiting times could differ according to hospital, depending on not only the size of the hospital and the number of annual visitors, but also on the patient's management capacity and the various structured and implemented processes analysed internally by the ED.

From our research, we concluded that it would be possible to increase the efficiency of services, reduce waste in terms of waiting times and improve the quality of the working environment for both patients and operators.[9]

A standard set applicable in the different EDs, of ED performance metrics could be uniformly implemented. However, these measures could be adopted in each country, establishing specific threshold levels as quality indicators.

The quality assessment of included studies in this review was not performed; however, this review aimed to evaluate the efficacy measures of ED departments. Based on our knowledge, this is the first review developed in Italy on ED efficiency and its major contribution to the scientific literature of surely having defined a mapping of the various indicators to evaluate the efficiency of EDs. In the future, it is indeed necessary to give uniform regulation and establish threshold values in order to make the ED more efficient.

A noteworthy element is given by the fact that the peaks of overcrowding in the emergency room (ER) determine undesirable and very significant consequences in terms of quality of care and safety for patients and operators.

These negative effects can manifest themselves in various ways; in particular, on patients:

- Reduced efficiency of the evaluation and treatment processes.
- Increase in waiting times.
- Reduction of the protection of confidentiality.
- Reduction of the level of satisfaction on the part of the patient.
- Increase in the phenomenon of expulsion from the ER before the completion of the clinical course.

The effects on the operators can be summarised as follows:

- Reduction of motivation and gratification.
- Increase in the incidence of the burn-out phenomenon.
- Increase in episodes of violence by users.

The analysis shows that in order to ensure that the problem is taken on board and allow for an adequate response to the needs of citizens who turn to the ER, a common commitment is required of all the institutional levels involved, the Company Strategic Departments and the Departments of the Hospital and Department, as well as of the various services that interact in the hospital setting and in the interface between the hospital and the territorial/home context. This is because the phenomenon cannot be considered an event exclusively pertaining to the ED, and therefore requires a multiplicity of systemic and local interventions, aimed at the correct planning of intrahospital care pathways.

In light of the above, it is quite clear that the management of the phenomenon of overcrowding in the ER does not represent a burden only for theER, but for the entire hospital and assistance system. Therefore, as part of health planning activities, provisions should be formulated to ensure the adoption in each healthcare and hospital unit of a plan for the management of overcrowding in the ED. We are convinced that this fulfilment will form a first useful requirement for the purpose of monitoring the degree of achievement of the result objectives assigned to the strategic departments.

Salient elements of the plan in question are:

- The identification of indicators for the correct detection of the phenomenon.
- The definition of the related criticality thresholds and timely response methods, proportionate to the levels of criticality detected, aimed at favouring/facilitating the process and hospitalisation phases, avoiding incongruous and uncomfortable stationing of patients in the ED.
- The methods of 'measurement' of the phenomenon must be uniform in all ERs and be based on a set of static and dynamic indicators, the detection of which must be carried out promptly and in real time over the entire 24-hour period.

A further development is represented by the calculation of specific mathematical algorithms which, taking into account the same variables, are able to 'photograph' the current level of overcrowding.

All the aspects analysed in our study imply that, despite a clear view of the main issues of the ED, further research remains necessary to better understand the reasons for the differences in triage practices and the problem of overcrowding in the world, in order to analyse the structured processes within the ED and understand their dynamics.

Acknowledgements This article acknowledges the '2nd Sustainable Solutions for Growth SSG 2019 conference' for publishing portions of the work as an abstract in their conference proceedings.

Contributors DDL: conceptualisation, methodology and writing—original draft. LD: methodology, writing—original draft, visualisation. LM: writing—review and editing, supervision. GS: formal analysis, writing—original draft. FC: formal analysis, writing—original draft. IS: resources, writing—original draft. GI: conceptualisation, writing—review and editing, supervision. MT: supervision, project administration.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information.

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	Author & Year of pubblication	**Country**	**Aim**	**Design**	**Study setting**	**Data Source**	**Nr of patients & Year of data collection**	**Intervention**	**Type of outcome**	**Outcome**	**Limitation**	**Conclusion**
1	Easter et al. 2019	Colorado, USA	to evaluate 9 different models on ED flow and patient-centered metrics	Quantitative, exploratory, causal study that adopted a DES based experimental analytic research	Urban, academic, tertiary care facility and a primary teaching hospital with approximately 101,000 patients per year	EMR	Model 1:5,161 Model 2: 7,108 Model 3: 4,296 Model 4: 5,996 Model 5: 8,357 Model 6: 5,043 Model 7: 7,040 Model 8: 8,427 Model 9: 5,328, Year 2013-2016	9 flow design models based on the interaction of 3 flow models (ESI, intake attending physician, and no split flow) and 3 physical design typologies (zero, one, and two internal-waiting areas)	-length of stay (min) -bed utilization rate (pt/bed/day) -door to provider (min) - LWBS (%) - movements per patient (n)	Mean (±SD) -Model 1: 268.6 (±130.1) Model 2: 209.6 (±115.5) Model 3: 338.5 (±168.4) Model 4: 229.2 (±129.2) Model 5: 183.3 (±114.3) Model 6: 303.2 (±161.3) Model 7: 211.4 (±127.8) Model 8: 175.2 (±113.1) Model 9: 274.9 (±156.8) -Model 1: 3.15 (± 0.95) Model 2: 4.40 (± 0.90) Model 3: 2.43 (± 0.57) Model 4: 3.54 (± 1.00) Model 5: 4.97 (± 0.90) Model 6: 2.91 (± 0.60)	-Single center analysis -3 different time periods for empiric data -Exclusion of boarding time excluded from the LOS - Restriction of internal-waiting area	DES model combining flow split by an intake-attending physician and multiple internal-waiting areas resulted in improved ED operational and patient centered metrics

										Model 7: 4.30 (± 1.00) Model 8: 5.02 ± (1.02) Model 9: 3.30 (± 0.61) -Model 1: 31.8 (± 23.6) Model 2: 13.9 (± 7.4) Model 3: 53.8 (± 29.3) Model 4: 26.3 (± 22.1) Model 5: 9.8 (± 6.9) Model 6: 44.7 (± 27.5) Model 7: 23.7 (± 19.6) Model 8: 9.6 (± 6.8) Model 9: 39.9 (± 26) -Model 1: 4.32 (± 1.16) Model 2: 2.50 (± 0.93) Model 3: 6.24 (± 2.02) Model 4: 3.17 (± 0.73) Model 5: 1.60 (± 0.41) Model 6: 4.58 (± 1.47) Model 7: 2.51 (± 0.52) Model 8: 1.17 (± 0.31) Model 9: 4.01 (± 1.23)		

										-Model 1: 3.2 (± 1.5) Model 2: 3.4 (± 1.6) Model 3: 1.7 (± 0.6) Model 4: 4.0 (± 1.8) Model 5: 4.1 (± 1.8) Model 6: 1.9 (± 0.7) Model 7: 4.2 (± 1.8) Model 8: 4.2 (± 1.8) Model 9: 2 (± 0.7)		
2	Woodward et al. 2019	Australia	to describes the impact of a new model of care and to present a comparison of several metrics of ED performance and patient flow	Retrospective study	Public facility hospital with 119 inpatient beds and approximately 35 000 ED patients per year	Information and databases system	2,660 (Year 2014) 5,078 (Year 2015), 1 January - 30 September (9 month periods, before and after the introduction of CDU)	CDU model	-access block (%) -NEAT (%) -ambulance ramping (n) -level three escalations (n)	Before vs after the opening of CDU -43.3% vs 26.7% -69.0% vs 70.1% -2027 vs 1239 -21 vs 5	-Retrospective and single center study -Admission and discharge times: possible confounders	CDU model resulted in significantly improved performance on a range of KPIs
3	De Anda et al. 2018	Texas, US	to present a quality improvement initiative	Modeling approach analysis	Urban hospital research department with 30,233 admission per week	TeleTracking database (included all patients admitted from the ED)	NR, 2016	Quality improvement initiative with a flow nurse coordinator	-time to transport an admitted patient from the ED to an inpatient bed (min)	Without vs with flow -104 vs 84	NR	The quality improvement initiative created an innovative method of improving patient throughput in the ED and

												increasing staff satisfaction
4	Garrett et al. 2018	US	to identify efficient processes to optimize flow of patients through the ED	Prospective pre/post-interventional cohort study (all ITT patients presenting to the ED during study period)	Tertiary care (level 1 trauma center) with 74 bed	Administrative database	222,713 patient/visits (107,217 and 114,833 12 months pre and post intervention respectively), 2-year period	Vertical split-flow model	-Door to provider (min) -provider to disposition (min) -disposition to discharge (min) -total ED LOS (min) -likelihood to recommend -physician overall patient satisfaction score -nurse overall patient satisfaction score	Pre vs post intervention Median -34 vs 36 -140 vs 128 -25 vs 25 -250 vs 233 Mean -83.9 vs 86. -86.7 vs 87.4 -85.3 vs 86.6	-Lack of randomization and unmeasured confounders -Ongoing initiatives in the facility -No recorded disaster activations or known events during the study period -Possible drift in the manner in which ESI acuity levels assigned during the study period -Additional staffing added to the ED during the study period: possible confounder -No physician, advance practice providers, nurse or technicians added to the departmental plan, during the study period	Initiation of a vertical split flow model was associated with improved ED efficiency

5	Improta et al. 2018	Campania, Italy	to improve the management of patients in the ED, focusing on increase the flow to the client/patient	Qualitative, quantitative and simulation analyses	Hospital with level II ED with approximately 94,000 patients per year	Historical and post-Lean access records	Pre-Lean: 16,563 Post-Lean: 17,147, January 2015 - June 2015 and April 2016 - June 2016	Lean thinking	-Patients with a yellow code examined within 30 min (%) -patients with a green code examined within 1 h (%) -patients with a green code not ~~sent to~~ hospitalized~~ation~~ with a stay time ≤ 4 h (%) -patients sent to hospitalization with a stay time ≤ 8 h (%) -lead time for red code (min) -lead Time for yellow code (min) -lead Time for green code (min) -lead Time for white code (min)	Pre vs post-lean: -53.6 vs 56.9 -52.6 vs 54.3 -94.8 vs 96.8 -99.8 vs 99.8 Mean (±SD) -72 (±36) vs 71 (±30) -151 (±100) vs 147 (±67) -164 (±116) vs 163 (±120) -160 (±173) vs -158 (±156) Mean (SD) - 00:22:54 (00:28:25) vs 00:21:24 (00:26:55) -01:47:55 (01:14:44) vs 01:41:55 (01:14:44) -02:31:02 (01:27:18) vs 02:19:12 (01:03:20) -04:18:57 (01:52:11) vs 04:01:07 (01:02:57)	NR	Lean Thinking application increases the efficiency of services, reduces waste in terms of waiting times and improves the quality of the working environment for operators, increases the performance of the ED (% of hospitalized patients according to triage codes and waiting times)

									-waiting time I – II triage (min) -waiting time I triage – taken into care (min) -waiting time taken into care – dismissal (min) -waiting time I triage – dismissal (min)			
6	Khanna et al. 2018	Adelaide, Australia	to identify optimal inpatient discharge time targets to support acute patient flow	Retrospective observational study with modelling process	Quaternary teaching hospital with approximately 70,000 annual ED	Hospital's electronic medical record with simulation software	~50,000, October 2011-December 2012	Early 7 different discharge scenarios (based on different % of discharged patients)	-NEAT performance (%) -bed occupancy (%) -inpatient LOS (%) -wait for inpatient bed – patients from ED (%) -wait for inpatient bed – all patients (%)	Change post vs baseline: Best scenario (4: 80% of patients to be discharged by 11 a.m.)/ Worst scenario (2: 35% of patients to be discharged by 11 a.m., 70% by 2 p.m. and 100% by 5 p.m.) -+16.2%/-5.7% --1.5%/-0.2%	-Single center and 15 months study -Performance metrics focused on a patient's immediate hospitalization -Lack of data on potential readmission -Modelling based on current administrative data -Patient flow changes based on	Optimizing discharge timing has the potential to deliver significant improvements to patient flow, bottle neck and alleviate overcrowding

									-bed days (%) -number of patients (%)	--1.6%/-0.3% --24.9%/-6.0% --23.5%/-5.7% --0.7%/-0.1% -+0.9%/+0.2%	simulations only	
7	McHugh et al. 2018	US	to focus on the impact on LOS of the ED Telehealth Express Care Service and provide a brief discussion of the application -facilitated virtual emergency -care service	Observational analysis	City hospital with > 95,000 ED visits per year (pediatric and psychiatric ED)	ED greeted and triaged patients	> 1,850 patients, July 2016 - October 2017	ED Telehealth Express Care Service	-LOS (hours) -patient-satisfaction score	Pre vs post intervention: -2.5 vs 38 minutes -91.3 vs 84.6	-Need for more rigorous investigation to determine the impact of the ED Telehealth	ED Telehealth has the potential to ease the stress of an overburdened health care system, enhance flow by expediting the care of lower-acuity patients and freeing up ED staff to attend to the critical, time-sensitive needs of sicker patients
8	Ngo et al. 2018	Australia	to assess the impact of the WA FHR program on multiple	A state population-based intervention study	4 tertiary and 1 general hospitals with approximat	Administrative health databases via record linkage and interrupted	3,214,802 ED presentation records (1,203,513 patients),	FHR program	-Access Block (%) - ED occupancy rate (%)	Pre-FHR Trend/FHR Change in Level/FHR Change in Trend (min	-Extensive range of ten outcome measures related to ED	WA FHR had a consistent effect on `flow' measures:

			measures of ED functioning and patient outcomes for 5 participating hospitals		ely 109,678 ED patients per year	time series analysis	January 2002 – December 2013		- ED attendances (%) -ED re-attendance (within 7 days of index ED discharge) (%) -EDLOS (hours)	and max among 5 hospitals) Mean -Hospital E: 1.017/0.989 /0.939 and Hospital C: 1.035/0.694/ 0.868 -Hospital C: 1.20% /0.23%/-0.80% and Hospital E: 1.95%/-0.95%/-6.23% -Hospital C: 6.62%/36.03 %/-5.57% and Hospital A: 0.18%/-8.78%/8.27% -Hospital A: 0.00%/0.04% /0.01% and Hospital E: 0.13%/-0.14%/-0.14% Median -Hospital E: 0.022/0.266/ 0.029 and Hospital A: 0.028/-0.559/-0.085	-Exclusion of factors such as patient age, comorbidity, mode of transport, socioeconomic disadvantage, system, environmental, seasonal factors and their interplay with the intervention effect -Limited generalizability	significantly reducing ED overcrowding and access block and enhancing ED efficiency
9	Potts et al. 2018	US	to implement an eSBAR	Observational project	Chicago, urban academic	Tool within the EMR designed by	NR, 10 month after the	Standardized Electronic Nursing	-ED RTM ~~Clean~~-to-	Before vs 3 weeks and 10 months after	NR	Implementing a standardize

			nursing hand off process nursing handoff process to decrease boarding time as measured by the RTM-to-occupied metric in the CMT	improvement initiative	medical center with 495-bed	the EMR vendor	implementation	Handoff Process	occupied time (min)	implementation Mean -84 vs 49 vs 47		d electronic handoff process can result in decreased ED crowding through a decrease in boarding time
10	Prang et al. 2018	Victoria, Australia	to evaluate the impact of the national healthcare reforms on ED time-based process outcomes	Quasi-experimental study	34 public hospitals with a designated 24-hour ED	Victorian Emergency Minimum Dataset (34 hospitals)	13,241,509 ED presentations (27.30%, in 6 major hospitals, 43.70% in 14 large hospitals, 23.59% in 9 medium hospitals, and 5.40% in 5 small hospitals), year 2006-2016	Government national healthcare reforms	-Waiting time to treatment (min) -treatment within recommended time (%) -departing ED within 4 hours of arrival (%)	Pre vs post ED targets Major/Large/Medium/Small hospitals Mean (±SD) -41.82 (±58.47) vs 35.18 (±45.79)/40.54 (±55.42) vs 36.64 (±49.31)/46.61 (±55.89) vs 41.36 (±54.23)/34.89 (±44.40) vs 32.69 (±41.51) -70.03%vs 73.22%/74.01% vs 74.24%/71.36% vs 73.27%/83.24% vs 83.35%	-Inclusion of confounding influences -No comparator group	Australian national healthcare reforms have encouraged improved ED patient waiting times, treatment within recommended time, and departure within 4 hours of arrival. However, the reforms were not able to stimulate attainment of the recommended Australian

										-52.20% vs 61.24%/60.19% vs 62.57%/71.95% vs 70.64%/85.38% vs 80.87%		national targets
11	Zheng et al. 2018	China	to measure the relative efficiencies of Chinese public hospitals	DEA multiple-input multiple-output non-parametric evaluation	84 public hospitals with > 30 out-patient and ED patients and visit, per year 2010-2016	Chongqing Statistical database	> 30 patients per year, year 2010 - 2017	Four-Stage-DEA	-Technical efficiency -pure technical, efficiency -scale efficiency	Pre vs post adjustment: Mean (SD) -0.862 (0.135) vs 0.890 (0.115) -0.882 (0.017) vs 0.913 (0.089) -0.975 (0.048) vs 0.972 (0.055)	-Influence of results for the index selection - Impact on the input slack variables from the external factors -High sensitivity of the results for inputs and time analysis	The new medical reform plays a significant role in improving the efficiencies of public hospitals
12	Ramos et al. 2017	Portugal	to assess the effect of an implementation of a dedicated medical team in ED and to compare 2 organisational models of delivering emergency care in medical ED	Pre-post study	Tertiary academic hospital with approximately 150,000 ED visits, per year	Hospital data	153,718 patients (153,300 visits), year 2002 and 2005/2006	2 medical staffing model: - classic model (with 12-h shift in the ED) -dedicated model (with full-time EM physicians)	- Hospitalisation rate (%) -total time in the ED (hour) - readmission rate at 24 h (%) -ED mortality rate (%) -LWBS rate (%)	2002 vs 2005 vs 2006 -24.7% vs 19.1% vs 17.3% Mean -04:34:00 vs 05:48:34 vs 05:50:25 -1.1% vs 1.0% vs 1.3% -0.4% vs 0.6% vs 0.5%	-Year of data (2002-2006) - Generalizability of results for imputation of HR medical costs -Lacked data on the number of exams and prescribed medication	Implementing a dedicated team of doctors increased the medical productivity and reduced costs in the ED

									-Productivity (patients treated/hour) -Cost with ED's medical hour (€)	-0.9% vs 1.4% vs 4.5% -0.13 vs 0.20 vs 0.27 -6,544,622€ vs 4,695,463€ vs 3,602,738€		
13	Rathlev et al. 2017	Australia	to calculate and improve the weekly means of daily outcomes for the measures of efficiency and productivity in ED	Before and after study	Tertiary-care referral center ED with > 30,000 visits per year	Integrated information technology system Cerner FirstNet	109,135, December 2012 - December 2015	Redesign of the ED operational nursing leadership	-Patients seen per day (n) -LWBS (%)	Before vs after Mean -265 vs 299 -8.2% vs 4.5%	-No control group -Single center study	Measures of efficiency and productivity can be improved significantly with a dedicated operational nursing leadership structure
14	Claret et al. 2016	France	to investigate the impact of a new ED organization on patients' mortality and management delays	Retrospective, before-after study	Tertiary care hospital with 76,000 inpatient admissions and 317,000 ambulatory visits per year	Hospital's electronic medical record system	83,322, year 2011-2012	ED segmentation and staffing increase	-24-hours in-hospital mortality -30-days in-hospital mortality -in-hospital mortality -FMC (min) -emergency room LOS (hour)	Before winter 2011 vs before summer vs before winter 2012 vs after summer 2012 -0.4% vs 0.3% vs 0.4% vs 0.3% -1.6 % vs 1.4% vs 1.6% 1.2%	-Single-center and retrospective study -Low applicable of organizational and architectural criteria -Lack of control for patient volume between the study periods	The segmentation of our ED has led to changes in nurse staffing and ED structural layout, but was associated with a reduction in overcrowding

									-inpatient LOS (days) -triage delays (min)	-1.5% vs 1.5% vs 1.8 vs 1.3% Winter vs summer 2012 Mean (±) -129 (±133) vs 104 (±95) -7 (±7) vs 6 (±9) -9 (±15) vs 8 (±11) -7 (±33) vs 3 (±33)		
15	Li et al. 2016	Taiwan, China	to investigate the impact of EP seniority on clinical performance	Retrospective and 1-year cohort study	A tertiary referral medical center and 2 secondary regional hospitals with for > 300,000 cumulative mean visits per year	Administrative database	68,282, July 2011-June 2012	Seniority of EPs	-Door to-order time (min) -door-to-disposition time (hour) -discharge rate (%) -ED revisit in 72 h (hour) -mortality rate (%)	Urgent vs non urgent (EP with ≤ 5 years/6 - 10 years/> 10 years) Median -10.2/10.7/12.4 vs 9.4/9.5/11.3 -1.7/1.7/2.0 vs 1.5/1.5/1.7 -33.4%/32.6%/32.4% vs 75.6%/74.8%/76.5% -4.3%/4.5%/2.9% vs 0.1%/0.1%/0.02% -3.0%/1.9%/3.	-No available data regard to technical quality and the appropriateness of clinical care -Limited collection of confounding factors taken into consideration	The experience of senior EPs is associated with a lower ED mortality rate

										0% vs 5.5%/5.3%/5.1%		
16	Pierce et al. 2016	Ohio, USA	to evaluate the split flow model of care delivery and a provider in triage model, comparing 2 EDs	Qualitative and comparative analysis	2 community hospital EDs with approximately 44,700 and 43,000 patients, per year	EMR	68,603. (33,977 from experimental site and 34,626 from control site), year 2014	Split flow model (+/- PIT)	-DLOS (min)	Traditional versus split flow model vs split flow model + PIT: Median -173.8 vs 157.5 vs 145.3	- Confounding variables not controlled - Generalizability of the results to a larger population	Split flow model, with or without PIT reduces the DLOS
17	Wiler et al. 2016	Colorado, US	to evaluate the impact of a multifaceted innovative ED work-flow redesign on key operational measures	Retrospective, observational, pre-post intervention, comparison study	Large academic urban hospital (Level 2 Trauma Center with burn, stroke, myocardial infarction and palliative care center) with approximately 74,000 ED visits per year	EMS	17,307 (pre-implementation) 27,443 (post-implementation) 34,481 (1 year – post implementation), December 2012, July 2013 – December 2013	Front-end split flow model	-LOS (min) -door-to-physician time (min) -LWBS (%) -LBVC (%)	Pre vs post vs 1 year post implementation: Median -216 vs 170 vs 140 -54 vs 15 vs 12 -5.5% vs 0.5% vs 0.0% -0.8% vs 1.1% vs 0.6%	-Single-center study -No blinding of staff and physician -Only incident reporting system used as surrogate marker for patient safety -Patient complaints not included -Physician, staff satisfaction and patient experience not included	A front-end split flow model was cost-efficient and significantly improved ED throughput measures
18	Green et al. 2014	Australia	to determine whether there are real differences in ED performance between Australian	Cross-sectional analysis	Public hospitals with > 100,000 ED visits per year	National non-admitted patient ED care database	> 5.8 million ED visits, July 2009 - June 2010	Triage scale and jurisdictional differences in ED	-Waiting times (min)	ACT vs NSW vs NT vs Qld vs SA vs Tas vs Vic vs WA: Mean -65.7 vs 38.5 vs 56.4 vs 47.6 vs SA 43.0 vs 52.0	NR	Although the Council of Australian Governments has adopted raw measures for ED performan

			states and territories							vs 41.7 vs 45.6		ce, there are no consistent differences in ED waiting times between states and territories
19	Cheng et al. 2013	Toronto, Canada	to examine the impact and limitations of adding 6.5 hours of MDRNSTAT on ED patient flow and quality of care	Cluster, randomized-controlled trial over a 26-week period	Academic tertiary level hospital with approximately 45000-patient/visits per year	2 computerized information systems (EPR and EDIS)	3,163 (control group) 2,387 (EP) 750 (MDRNSTA) 3,137 (EP + MDRNSTAT): 3137, October, 2009 - April, 2010	MDRNSTAT (+/-EP)	-CTAS 2-3, EDLOS for discharged (hour) -CTAS 4-5, EDLOS for discharged (hour) -LWBS (%) -Mortality (%) -BW request Time (hour) -DI Request Time (hour) -Consult Request Time (hour)	Non consulted and consulted (control vs EP vs MDRNSTAT vs EP+MDRNSTAT) Median --4:29 EP vs 4:07 vs 4:01 vs 4:05 and 7:19 vs 7:06 vs 6:25 vs 6:48 -2:06 vs 2:08 vs 1:10 vs 1:55 and 4:57 vs 4:40 vs 4:19 vs 4:40 -2.22% vs 1.9% vs 0.53% vs 1.50% -0.16% vs 0.08% vs 0.0% vs 0.06%	-Single-center, not blinded study and not completely randomized -Inclusion only coverage on weekdays	The MDRNSTAT was effective in decreasing EDLOS, physician initial assessment time and LWBS of discharged patients requiring ED services, without compromising the quality of patient care

										-1:47 vs 1:42 vs 1:02 vs 1:32 -2:16 vs 1:56 vs 0:51 vs 1:38 -3:20 vs 2:59 vs 2:40 vs 2:54		
20	Lim et al. 2013	Canada	to present an alternative approach and to compare it with the traditional approach	Modelling analysis	Academic hospital with a ED opened 24 hours and approximately 50,000 patients per year	Centralized database	15,196, April - July 2010.	Interacting pseudo-agents approach	-Patient waiting time for treatment (min) -LOS (min)	Without vs with interactions (physician high acuity/physician low acuity/delegate low acuity) Mean -0.49/0.56/0.15 vs 1.02/1.49/0.52 -85.91/118.54/114.84 vs 86.83/136.99/142.07	-Exclusion of junior and senior delegates -The entire patient flow or possible variations in routing and some complexities of the ED not included -Possible underestimate of total LOS and resource utilization -Implication of commercially available software	The interaction between physician and delegate can have an impact on predicted patient throughput and waiting time
21	Muntlin et al. 2013	Sweden	to investigate the effects of teamwork in a ED on lead times and patient flow	Longitudinal, non randomized intervention study with a mixed-method design	University (level 1 trauma) hospital with > 55,000 patients per year	EMR and Electronic tracking system	2,562 patients, 10 weeks (3 follow-up periods: 5, 11 and 16 months)	Introduction of multi-professional teams by reorganization of the work processes	-Patients handled within teamwork time (%) -patients handled within the 4-hour target (%)	Control vs intervention vs 5 vs 11 vs 16 months -71% vs 73% vs 72% vs 67% vs 76% -59% vs 60%-65% (range for	-Study set in the ED's section of internal medicine -2-week periods -Staff not blinded -Use of registry data	Teamwork system seems to contribute to quality improvement ED in terms lead time, improve patient

									-time to physician (min)	intervention group and 5 and 11 months group) vs 71% Control vs 16 months: Median -53 vs 42	for time report	safety by fostering a safer and accurate communication between staff members and patients
22	Storm-Versloot et al. 2013	Amsterdam, Netherlands	to compare performance measures over levels of urgency before and after the implementation of the MTS at an ED	Prospective, single-center, 'before' and after' study	University teaching hospital (with a level 1 trauma center with >31 000 attended patients per year)	Clinical records and patient form	907 (before implementation) 901 (after implementation), October 2007	Implementation of the MTS	-Entrance time (hours and min) -waiting time (hours and min) -treatment time (hours and min) -LOS (hours and min)	-Before vs after implementation: Median -0.05 vs 0.02 -0.10 vs 0.12 -1.06 vs 1.20 -1.30 vs 1.45	-Before and after test design -Relatively long time interval -Mediocre response rate between both measurements	Implementing MTS is not sufficient to improve the efficiency and quality of EDs
23	Casalino et al. 2012	Paris, France	to determine the association between ED quality, input and output associated variables	1 year, prospective, observational, cohort study	University hospital with approximately 60,000-65,000 visits per year	EMR	67,307, April 2009 – March 2010	EDQPI	-Time to triage nurse (min) -time to ED provider (min) -patients admitted to hospital (%) -LOS (min)	Bad day vs best day Mean (±SD) -13 (±4) vs 10.9 (±3.2) -78.1 (±18.3) vs 59.2 (±11.4) -59.3% vs 39.0% Non admitted and admitted -181.7 (±25.6) vs 144.6 (±19.4) and 328.7	-Quality of performance indicator of ED not only accepted -Effect of study design on casual changes in patient flow -Use of administrative data collected for pilotage purposes -Lack of data information about hospital	Measurement of time interval metrics is a useful tool to evaluate ED processes , performance and quality of care

										(±78.9) vs 286 (±88.8)	occupancy rates, processes of care and organizational procedures	
24	Hogan et al. 2012	Hamburg, Germany	to create an improved working ED (that cuts patient waiting times for first specialty physician contact)	Observational, comparative treatments month study	Hospital with approximately 43,498 patients (year 2008) and 57,641 patients (year 2010)	Hospital contacts	3,230 (February 2008, without intervention) and 3,269 (February 2010, with intervention)	First View Concept	-Waiting time before first doctor contact (min)	Before vs after intervention Median -47.6 vs 11.2	NR	A reduction in waiting times can be achieved by new forms of organization based on industrial flow principles
25	Nestler et al. 2012	Rochester, UK	to evaluate whether a PA, acting as a TLP, would shorten LOS and decrease LWBS rates	Observational cohort, controlled, before-and-after study	Academic tertiary care hospital (Level I trauma center) with approximately 72,000 patient/ visits per year	EMR and electronic ED tracking system	371 (control dates) 353 (pilot dates), May 2, 4, 9, 11, 16, 18, 25, June 1 and April 4, 6, 11, 13, 18, 20, 28, 30, 2011	TLP	-LOS (min) -Waiting room (min) -Treatment room (min) -LWBS (%)	Control vs pilot dates Median -270 vs 229 –70 vs 69 -187 vs 151 -9.7% vs 1.4%	-Single-center study -TLP shifts or the days not randomized -Exclusion of other co-interventions during the study periods	The addition of a PA as a TLP was associated with a decrease in median total LOS, and a lower proportion of patients who LWBS
26	Welch et al. 2011	Salt Lake City, US	to describe how 2 community hospital EDs improved door-to-physician times using reliability tools and strategies	Prospective data analysis	2 community hospitals (Cottonwood and Alta View) EDs with approximately 53,000 and 28,000 visits per year	ED Data Mart: home grown information system and data repository	81,000 census (for 3 months prior to the study period and 7 months of the study period), October 2005 - June 2006	3 reliability strategies of door-to-physician improvement project: -prompts and reminders -awareness and training; -feedback loop	-Door-to-physician time (min) -LWBS (%)	Before intervention vs after intervention (Cottonwood /Alta View) Median Hospital) -51/47 vs 31/27	-Generalizability of result due to use of homegrown tracking system -ED physician group and a health care	The tools had a positive effect and both hospitals showed significant and sustained improvement

										-3%/2% vs -2%/1.4%	system as data source -Possible confounder due to physicians recording activities	
27	Baumlin et al. 2010	New York City, US	to evaluate implementation of a fully integrated EDIS	Observational, pre-post intervention study	Hospital with approximatively 75,677 (year 2001) and 76,903 (year 2005) ED visits	Hospital electronic data repository with patient tracking	508 (pre-intervention 691 (post-intervention), year 2001 and 2005	EDIS	-LOS (hour) -Door to doctor time (hour) -Doctor to disposition time (hour) -Disposition to discharge time (hour) -CT TAT (hour) -Laboratory TAT (hour) -X ray TAT (hour)	Pre vs post intervention Median -6.69 vs 4.75 -1.22 vs 0.68 -3.64 vs 1.74 -6.77 vs 4.90 -3.89 vs 2.33 -2.03 vs 1.44 -0.92 vs 0.74	-Additional work for department staff for data entry -4 year difference between the 2 data collection periods of the study -Changes within the ED that occurred during post intervention data collection period: possible confounders	EDIS implementation and process redesign led to decreased patient throughput times and improved ED efficiency
28	Ng et al. 2010	Windsor, Ontario Canada	to improve recognition of ED measures	Before and after study	ED regional referral hospital center with approximately 450,000 patients and 55,000 ED visits per year	Hospital health records	820, April 2005 - September 2005/ October 2005 - March 2006/ April 2006 - March 2007	Lean principles of the Toyota Production System	-Time to see a physician (min) -LOS (hour)	Before Lean (year 2005) vs after Lean (year 2006) vs after Lean (year 2007) Mean -111 vs 89 vs 78	-Lack of an ED information system and a central visual signal -Limited generalizability	Lean manufacturing principles can improve the flow of patients through the ED,

									-patients who LWSP (%) -overall patient satisfaction score (%) -admitted inpatients in the ED at 6:00 am (n)	-3.6 vs 3.3 vs 2.8 -7.1% vs 5.0% vs 4.3% -79.8% vs 82.0% vs 83.1% -1.8 vs 4.1 vs 6.1	-Possible incorrectly assigned and reassigned patients procedures	resulting in greater patient satisfaction along with reduced time spent by the patient in the ED

ACT Australian Capital Territory

BW BloodWork

CDU Clinical Decision Unit

CMI Case Mix Index

CMT Capacity Management Technology

CTAS Capacity Assigning Acuity Scores

DEA Data Enveloping Analysis

DES Discrete Event Simulation

DLOS Discharge length of stay

ED Emergency Department

EDDC Emergency Department Data Collection

EDIS Emergency Department Information System

EDQPI ED Quality and Performance Indicator

EMR Electronic Medical Record

EP Emergency Physician

EPR Electronic Patient Records DI Diagnostic Imaging

eSBAR: electronic Situation, Background, Assessment and Recommendation

ESI

FHR: Four-Hour Rule

FMC First Medical Contact

HMDC Hospital Morbidity Data Collection

ITT Intend-To-Treat

KPI Key Performance Indicator

LBVC Left Before Visit Complete

LWBS Left Without Being Seen

LWSP Left Without Seeing a Physician

MDRNSTAT Physician (MD) - Nurse (RN) Supplementary Team At Triage

MTS Manchester Triage System

NR Not Reported

NSW New South Wales

PA Physician Assistant

PIT Provider In Triage

RTM Ready To Move

TAT Turn Around Time

TLP Triage Liaison Provider

WA-FHR Wester Australia - For Hour Rule