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**Interventions to improve patient flow in emergency departments: an umbrella review**

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## ABSTRACT

### Objectives

Patient flow and crowding are two major issues in emergency department (ED) service improvement. A substantial amount of literature exists on the interventions to improve patient flow and crowding, making it difficult for policymakers, managers and clinicians to be familiar with all the available literature and identify which interventions are supported by the evidence**.** This umbrella review provides a comprehensive analysis of the evidence from existing quantitative systematic reviews on the interventions that improve patient flow in emergency departments.

### Methods

An umbrella review of systematic reviews published between 2000 and 2017 was undertaken. Included studies were systematic reviews and meta-analyses of quantitative primary studies assessing an intervention that aimed to improve ED throughput.

### Results

The search strategy yielded 623 articles of which 13 were included in the umbrella review. The publication dates of the systematic reviews ranged from 2006 to 2016. The 13 systematic reviews evaluated 26 interventions: full capacity protocols, computerized provider order entry, scribes, streaming, fast track and triage. Interventions with similar characteristics were grouped together to produce the following categories: diagnostic services, assessment/short stay units, nurse directed interventions, physician directed interventions, administrative/organizational and miscellaneous.

The statistical evidence from 14 primary RCTs was evaluated to determine if correlation or clustering of observations was considered. Only the fast track intervention had moderate evidence to support its use but the RCTs that assessed the intervention did not utilize statistical tests that considered correlation.

### Conclusions

Overall, the evidence supporting the interventions to improve patient flow is weak. Only the fast track intervention had moderate evidence to support its use but correlation/clustering was not taken into consideration in the RCTs examining the intervention. Failure to consider the correlation of the data in the primary studies could result in erroneous conclusions of effectiveness.

What is already known on the subject

- Patient flow is a major issue in emergency department service improvement.
- An extensive volume of literature exists on the interventions to improve patient flow.
- An umbrella review provides a comprehensive analysis of the evidence from existing systematic reviews on the interventions that improve ED patient flow.

What this study adds

- The evidence supporting the interventions to improve patient flow is weak.
- Only the fast track intervention had moderate evidence to support its use but clustering of data was not taken into consideration in the RCTs examining the intervention.
- Failure to consider the clustering of data may produce misleading conclusions regarding the effectiveness of the intervention.

## INTRODUCTION

Patient flow and crowding are two major issues in emergency department (ED) service improvement. Although previously published literature have used these terms interchangeably, in order to suggest better quality improvement measures, it may be necessary to distinguish between the two terms. In 2006, Asplin advocated for a shift in focus from ED crowding to patient flow [1]. In Asplin's view, measuring crowding may be unproductive and suggested a shift from crowding to flow measurements, recognizing that measuring patient flow may be more achievable and useful to improve ED care [1].

Consensus definitions and measures of ED patient flow and crowding do not yet exist. For this review, patient flow may be described in terms of the progressive movement of patients through care processes from arrival until the patient physically leaves the ED, with movement referring to the conversion of an input into an output [2, 3]. ED crowding may be described in terms of an imbalance between the demand and capacity to provide care [4].

Hwang et al. further simplify crowding measurements, categorizing it as flow and non-flow, where non-flow leads to crowding [5]**.** Asplin suggested that the 'fundamental metric of patient flow is throughput' which may be measured using ED throughput time, that is, time from patient arrival to exit in the ED [1]. In terms of metrics, it may be inferred from Hwang et al. that patient flow may be measured using time-intervals, while non-flow (crowding) be measured by using numerical counts [5].

ED quality indicators from Hospital Episodes Statistics UK and the National Ambulatory Medical Care Survey in the US include measures such as time to treatment, time to initial assessment, total time in the ED [6, 7]. This is consistent with Asplin's measure of ED throughput time and Hwang et al.'s suggestions to use time intervals to measure patient flow.

Although this review attempts to separately consider patient-flow and non-flow (crowding), a close relationship does exist between the two. A crowded ED may result in poor patient flow because of the demand for care. In other words, the number of patients exceeds the capacity to match that demand and consequently this will lead to a downstream effect on the progressive movement of patients, thus hindering patient flow [8]. In an ED with poor patient flow, patients may not move through the processes of care at an adequate rate, which eventually may result in ED crowding [8]. Thus it is possible that identifying factors that optimize patient flow may also address crowding.

A substantial amount of literature exists on the interventions to improve patient flow and crowding. An initial quick search in Medline for studies exploring ED patient flow, identified 266 primary studies, 18 systematic reviews and 11 other review types. Reviews assessed specific interventions, making it difficult for policymakers, managers and clinicians to be familiar with all the available literature and identify which interventions are supported by the evidence**.** Hence, to improve the ED in a holistic manner, policymakers, managers and clinicians may have to familiarize themselves with all the available literature. This may prove to be a difficult task for managers and clinicians.

A comprehensive review of the literature should assist in identifying and assessing the evidence base, and subsequently choosing effective interventions to improve ED patient flow. One method to accomplish this is to compile the evidence from existing systematic reviews. The Cochrane Collaboration describes this as an overview of reviews or Cochrane Overviews [9]. The Joanna Briggs Institute, an international research institute in Australia, uses the term umbrella review, defined as "an overview of existing systematic reviews" [10]. An umbrella review synthesises the evidence from published systematic reviews, selecting reviews based on predetermined criteria without delving much into the quality of the individual primary studies included in the original systematic review.

A systematic review systematically searches for, appraises and synthesises evidence, usually following specific guidelines [11]. Hence, an umbrella review should encompass all similar systematic reviews on a specific topic, crystallising the evidence, in an attempt to assist managers and clinicians to improve their departments in an evidence-based manner.

With this background, this umbrella review aims to summarise the evidence from systematic reviews on the interventions that improve patient flow in emergency departments

## METHODS

We compiled evidence from systematic reviews that analysed quantitative primary studies addressing interventions to improve ED patient flow.

### Eligibility criteria

Reviews were eligible if they satisfied the following criteria:

- Full text systematic reviews published between 2000 and 2017 in English language
- Searched at least 2 electronic databases
- Systematic reviews and meta-analyses of quantitative primary studies; (systematic reviews including both quantitative and qualitative data were included only if the data was analysed separately)
- ED must be the primary study site
- Must include any intervention, strategy that targeted ED throughput
- Outcome measures (as metrics of patient flow) must have been defined; described in terms of any time-interval e.g., Length of stay (ED LOS) and any of its sub-measures

Reviews were excluded if any of the following were present:

- Focused on disease specific conditions
- Intentionally focused on country-specific literature
- Primary focus was ED crowding (e.g., outcomes were crowding measures, defined as numerical counts such as number of patients in ED)
- Non-systematic reviews
- Qualitative evidence syntheses
- Systematic reviews based on theoretical studies, opinions, editorials, commentary

**Search strategy**

A comprehensive search strategy, restricted from January 2000 to April 2017, was used to identify articles. Six databases were searched-Medline via Ovid (1946-present), EMBASE (1974 to July 2016), CINAHL (1982 to present), Cochrane Library, JBI for Systematic Reviews and Implementation reports, Proquest. Three search concepts were used- "emergency department", "patient flow" and "crowding". Systematic review search filters were applied to the search strategy as outlined by Lee et al. [12] and Lunny et al. [13]. See online supplementary 1 for sample search strategy.

OpenGrey and Google Scholar were searched for grey literature. Citation tracking was conducted in Google Scholar, Web of Science and Epistemonikos. Reference lists of the included articles were reviewed. Conference proceedings identified in the electronic database search were checked for full text versions and authors contacted if necessary.

**Data extraction and quality appraisal**

Two authors (LD and SH) independently reviewed the systematic reviews extracting data using a data extraction form developed by the Joanna Briggs Institute [10] and ranked the quality using A Measurement Tool to Assess Systematic Reviews (AMSTAR 2) tool (online supplementary 2) [14]. Differences were settled after discussions to reach a consensus. The quality appraisal of the primary studies identified in the systematic reviews was extracted from each systematic review. The authors of the umbrella review did not perform a new quality appraisal for these primary studies as an umbrella review usually only includes a quality appraisal of the systematic reviews rather than the quality of the primary studies.

**Data synthesis**

The results were summarised and presented in a tabular form supported by a narrative synthesis. The results were presented based on each intervention and outcome measure.

Given the high heterogeneity across the reviews no additional statistical analyses were conducted.

Analysis of the appropriateness of the statistical analyses was undertaken in a subset of primary studies, to explore the issue of whether potentially correlated data had been addressed. Measures of patient flow, like measures of ED crowding, may be subject to substantial correlation between individuals, which if not taken into account could lead to the wrong conclusion being drawn. This statistical review was performed by SH and LD.

## RESULTS

### Results of the search process

617 articles were retrieved from the six databases. Six studies were found through reference lists and citation searching. 404 articles were screened at the title stage. Thirteen full text articles were included in the final review. The PRISMA flowchart of the study selection [15] is depicted in Figure 1.

### Description of included systematic reviews

The publication dates of the thirteen reviews ranged from 2006 to 2016 [16-28]. The publication dates of the primary studies ranged from 1995 to 2015. Six of the reviews used the term 'crowding' in their titles but had time interval outcome measures which made them suitable for assessing patient flow [17, 18, 21, 26-28]. There were 20 randomised control trials (RCT) and 200 non- RCTs. Of these non-RCTs, 125 studies had before-after designs. The primary studies originated from 20 countries. Participant numbers totaled over 2 million.

The general characteristics of the systematic reviews are presented in table 1. The majority of the reviews were graded as moderate to high quality based on the AMSTAR 2 score. Many of the primary studies were weak, mostly belonging to the before-after study design. The systematic reviews conducted by Elder [19], Georgiou [20] and Jennings [23] did not present

quality assessments of the primary studies. The review by Bond [17] presented a quality assessment but an interpretation of the scores was not provided. The publication agency for that review was not able to provide further information on the quality assessment.

A summary of the quality appraisals of the primary studies and the AMSTAR 2 scores is presented in online supplementaries 3 and 4.

**Table 1. General characteristics of the systematic reviews**

| Systematic review | Aim | Period of study | No. of primary studies | No. of participants | Countries | Study designs | Intervention | Analysis method | Flow metric |
|---|---|---|---|---|---|---|---|---|---|
| **Abdulwahid, 2016 [16]** | Impact of senior doctor triage *versus* the standard single nurse triage | 1994-2014 | 25 | 690, 232 (24 studies) | 12 USA<br>5 Australia<br>2 UK<br>2 Canada<br>1 each Hong Kong Jamaica Singapore Sweden | 4 RCT<br>2 CCT<br>3 Cohort<br>16 BA | Senior doctor triage | Meta-analysis | ED LOS<br>Waiting times |
| **Bond, 2006 [17]** | Effects of interventions designed to reduce or control ED overcrowding | Until Dec 2004 | 66 | Not available | 29 US<br>13 Canada<br>9 UK<br>5 Australia<br>3 Spain,1 each Hong Kong Israel New Zealand Singapore Sweden Switzerland Turkey | 2 RCT<br>7 CCT<br>7 Cohort<br>50 BA | Fast track, multi-faceted interventions, staffing changes, triage, physician order entry, short stay units, unique interventions | Descriptive | ED LOS<br>Waiting times |
| **Bullard, 2012 [18]** | Impact of rapid assessment zones/pods to mitigate ED overcrowding | 1966-May 2009 | 4 | 23,189 | 2 Canada,<br>1 New Zealand<br>1 Saudi Arabia | 1 RCT<br>1CCT<br>2 BA | Rapid assessment zones/pods | Descriptive | ED LOS<br>Physician initial assessment |
| **Elder, 2015 [19]** | Effectiveness of 3 current models of ED care. | 1980-2014 | 21 | 105,413 (20 studies) | 7 Australia<br>6 UK<br>3 Canada<br>2 USA<br>1 each Ireland Singapore Sweden | 1 SR<br>4 RCT 1 QE<br>2 CCT<br>3 Retro 2 Pro<br>1 Sur<br>6 BA | Expanding nursing roles, Physician assisted triage, Medical assessment units | Descriptive | ED LOS, Patient off stretcher times |
| **Georgiou, 2013 [20]** | Effect of computerised provider order entry on clinical care and work processes | Jan 1 1990-May 31 2011 | 22 | 61,851 (18 studies) | 20 USA<br>1 Korea<br>1 France | 2 RCT<br>2 Pro<br>2 TS<br>16 BA | Computerised provider order entry | Descriptive | ED LOS |

SR= systematic review RCT= randomised controlled trial CCT= controlled clinical trial QE= Quasi-experimental
Retro = retrospective Pro = prospective TS= time series Sur = survey BA= before-after

**Table 1. General characteristics of the systematic reviews**

| Systematic review | Aim | Period of study | No. of primary studies | No. of participants | Countries | Study designs | Intervention | Analysis method | Flow metric |
|---|---|---|---|---|---|---|---|---|---|
| **Guo, 2006 [21]** | Effectiveness of strategies to reduce ED overcrowding | Sept 1993-Dec 2005 | 25 | Not available | 9 US<br>7Australia<br>4 Canada<br>1 each UK Spain Switzerland | 2 SR<br>1 RCT<br>2 cohort<br>20 BA | ED staffing/ reorganisation, fast track, access to diagnostic services, system wide interventions | Descriptive | ED LOS<br>Waiting times |
| **Heaton, 2016 [22]** | Effects of scribes on patient throughput, billing and patient and provider satisfaction | 1946-May 2015 | 17 | 231, 129 (10 studies) | 14 US<br>1 Canada<br>1 Germany 1 Australia | 1 RCT<br>5 Retro<br>4 Pro<br>1 Sur<br>6 BA | Medical scribes | Meta-analysis | ED LOS<br>Door to room<br>Room to doctor<br>Time to disposition<br>Patients per hour |
| **Jennings, 2015 [23]** | Impact of emergency nurse practitioner on cost, quality of care, satisfaction and waiting times in ED | 2006-2014 | 14 | 36,621 | 4 Australia<br>1 New Zealand<br>2 UK<br>1 US<br>1Netherlands,<br>1 Canada | 2 SR<br>2 RCT<br>1 cohort<br>2 Pro<br>2 audit<br>3 Sur<br>1 CC<br>1 CS | Nurse practitioners | Descriptive | Waiting times |
| **Ming, 2016 [24]** | Impact of team triage on ED patient flow | Start of database to June 30 2015 | 4 | 14,772 | 2 Canada<br>1 US<br>1UK | 4 RCT | Team triage | Meta-analysis | ED LOS<br>Waiting times |
| **Oredsson, 2011 [25]** | Explore which interventions improve ED patient flow | 1966-March 31 2009 | 33 | 503, 770 | 9 Australia, 7 US<br>5 UK<br>4 Canada<br>1 each New Zealand Northern Ireland Spain Singapore Turkey Saudi Arabia | 9 RCT<br>21 BA<br>1CCT | Triage related interventions (fast track, streaming, team triage, POCT, nurse requested X-ray) | Descriptive | ED LOS<br>Waiting times |
| **Rowe, 2011a [26]** | Effectiveness of triage liaison physicians on mitigating the effects of overcrowding in EDs | 1966-Dec 2005 | 28 | 406, 184 (20 studies) | 17 USA<br>4 UK<br>2 Hong Kong,<br>2 Australia<br>2 Canada<br>1Singapore | 2 RCT<br>7 CCT<br>1 ITS<br>2 Pro cohort<br>16 BA | Triage liaison physician | Meta-analysis | ED LOS<br>Physician initial assessment time |

SR= systematic review RCT= randomised controlled trial CCT= controlled clinical trial QE= Quasi-experimental
Retro = retrospective Pro = prospective TS= time series CC- case control Sur = survey BA= before-after

**Table 1. General characteristics of the systematic reviews**

| Systematic review | Aim | Period of study | No. of primary studies | No. of participants | Countries | Study designs | Intervention | Analysis method | Flow metric |
|---|---|---|---|---|---|---|---|---|---|
| **Rowe, 2011b [27]** | Effectiveness of triage nurse ordering on mitigating the effect of overcrowding in EDs | 1966-Dec 2005 | 14 | 24, 096 | 3 USA<br>3 Canada<br>2 UK<br>2 Australia<br>1each Singapore Denmark Netherlands Hong Kong | 3 RCT<br>1 CCT<br>2 Retro cohort<br>3 Pro cohort<br>2 CC<br>3 BA | Triage nurse ordering | Descriptive | ED LOS<br><br>Physician initial assessment time |
| **Villa-Roel, 2012 [28]** | Effectiveness of Full Capacity Protocols on overcrowding | 1966-May 2009 | 5 | 128,082 (4 studies) | 3 Canada<br>1 US<br>1 UK | 1 CCT<br>1 ITS<br>3 BA | Full capacity protocols | Descriptive | ED LOS |

SR= systematic review RCT= randomised controlled trial Retro = retrospective Pro = prospective ITS- interrupted time series
Sur = survey BA= before-after CC= case control CS= case series

## Review findings

### Description of interventions

The 13 systematic reviews evaluated 26 interventions: full capacity protocols, computerized provider order entry, scribes, streaming, fast track and triage. Interventions with similar characteristics were categorized as follows: diagnostic services, assessment/short stay units, nurse directed interventions, physician directed interventions, administrative/organizational and miscellaneous. A description of the interventions based on the information presented in the study (s) that assessed it is in Table 2.

### Statistical evidence from primary RCT studies

The correlation of observations in the ED is a potential issue in the statistical analyses of the reviews and primary studies [29, 30]. Many standard statistical tests assume that the observations are independent [29, 30]. An independent observation assumes, for example, that the waiting time of one patient is not correlated with the waiting time of another but this is unlikely to be true in the ED since patients arriving at similar times are also likely to have similar waiting times. Therefore, it is important to consider the dependent nature of the observations when analyzing data. Using tests that do not consider dependency or correlation may result in the incorrect estimation of the p value with misleading conclusions [29].

Ming et al. [24] discussed the correlation issue in their review. Since only one systematic review made reference to the issue, the statistical tests used in a subset of primary studies were examined. Given the substantial number of primary studies that would have to be assessed together with the complexity of the statistical issue, the decision was made to focus only on randomized control trials. Randomized control trials have stronger study designs that can provide reliable evidence once analysed appropriately. While non-randomised designs are likely to be at an even greater risk for correlation and clustering issues, these designs, particularly the before-after studies, are already at high risk of bias even if analysed appropriately. In each systematic review, randomized control trials that assessed a flow metric were extracted and included. Fifteen RCTs assessed the outcome measures of interest and fourteen articles were located (S1-14). See online supplementary 5 for the statistical review of RCTs.

**Table 2. Description of interventions**

| Intervention | Definition |
|---|---|
| Full capacity protocols | *A method to distribute admitted patients throughout the hospital, usually to temporary areas, when EDs have reached maximum capacity [28]* |
| Computer provider order entry | *An electronic system used to enter patient data [20]* |
| Scribes | *Non- medical persons whose role is to assist clinicians with non- clinical aspects of patient care such as documentation of patient notes and retrieval of investigations [22]* |
| Streaming | *The categorization of patients with similar characteristics (complaint or likely disposition status) into distinct pathways where they can receive tailored care [25]* |
| Fast track | *A separate pathway for patients with minor complaints [17,25]* |
| Triage | *The process of sorting patients based on acuity and urgency of illness [17]* |
| **Diagnostic services** | |
| Point of care testing | *Laboratory analysis that occurs in the ED [25]* |
| Advanced triage | *A triage nurse who is allowed to order diagnostic tests [21]* |
| **Assessment and short stay units** | |
| Rapid assessment zones | *Distinct spaces in the ED for patients with ambulatory complaints who can be treated without utilizing a bed [18]* |
| Short stay units | *Designed for patients who require a short period of observation before a disposition decision can be made [17]* |
| Medical assessment units | *Areas for patients with complex medical conditions who likely require admission [19]* |
| **Nurse directed interventions** | |
| Nurse practitioner | *An independent nurse who is qualified to assess, diagnose and treat certain medical complaints [23]* |
| Triage nurse ordering | *Nurse initiated activities at triage (nurses may or may not have had training) [27]* |
| Nurse requested X-rays | *X-rays for limb injuries requested by nurses [25]* |
| Clinical initiative nurse | *An advanced nursing role where nurses can initiate activities [19]* |
| **Physician directed interventions** | |
| Physician assisted triage | *Presence of a physician at triage who is able to expedite patient throughput [19]* |
| Triage liaison physicians | *Physicians and triage staff work together to manage patients at the point of triage [26]* |
| Senior doctor triage | *Placement of a senior doctor in triage to assist in the management of patients prior to being seen in the main ED [16]* |
| Team triage | *A triage team that includes a physician [25] or triage performed by a team composed of at least two medical personnel, either a nurse or physician [24]* |
| **Administrative and Organisational interventions** | |
| Multifaceted | *Multiple strategies such as structural reorganization, implementation of coordinators, changing staffing numbers or introducing longer opening hours for other services [17]* |
| System wide interventions | *Interventions that addressed more than one component in Asplin's three component model [21]* |
| Staffing changes/ ED staffing/re-organisation | *Interventions that focused on changing staffing numbers or re-structuring the ED [17,21]* |
| **Miscellaneous** | |
| Dedicated ED radiology staff | *Technical radiology staff dedicated to the ED [17]* |
| Electronic board tracking | *An electronic system that provides up to date information on patients' status [17]* |
| Bedside registration | *Registration occurring at the patient's bedside [17]* |

Summary of findings

A summary of findings for each intervention, based on each outcome measure, is presented in tabular form together with a narrative synthesis. Overlap of primary studies in reviews assessing the same intervention is highlighted in the summary tables.

The summary of findings for full capacity protocols, computerized provider order entry, scribes, streaming, fast track, triage, diagnostic services, assessment and short stay units are presented in table 3; nurse and physician directed interventions are presented in tables 4 and 5; administrative/organizational and miscellaneous interventions are in table 6.

1. *Full capacity protocols (FCP)*

This was evaluated in one BA (before-after) Canadian study from one systematic review. The full capacity protocol significantly improved ED LOS for all admitted patients [28]. However, as the review was based on one weak quality study, in abstract form, it is difficult to draw conclusions.

2. *Computerized provider order entry (CPOE)*

Two reviews examined the effect of CPOE on patient flow [17, 20]. The results were derived from studies conducted in the US and Canada. Bond et al. reported a decrease in ED LOS in two non-RCT studies and an increase seen in 1 BA [17]. Two BA studies in the Georgiou review reported decreases in LOS (-1.94 hours, 95% CI 0.79 to 3.09 hours; -30 minutes, 95% CI 28 to 33 minutes) while two reported increases in LOS (17.4, 95% CI 8.7 to 26.2 minutes; 36 minutes, 95% CI 26 to 46 minutes) [20]. The Georgiou et al. review concluded that CPOE had inconsistent effects on ED LOS [20].

3. *Scribes*

The impact of scribes on patient flow was examined in one review that compared services with scribes to those without [22]. The settings included 6 academic and 2 community emergency departments across the US (6), Canada (1) and Australia (1). The primary studies were based on non-RCT designs and those

assessing LOS were high (1) and moderate (4) risk of bias. Meta-analyses performed by the review authors found that scribes had no difference on ED LOS and provider to disposition time.

There was a statistically significant but small increase in the number of patients seen per hour. There were no pooled results comparing the effect of scribes in academic versus community EDs so it is unclear if the type of ED setting affected the results. The review concluded that evidence was limited for the use of scribes [22].

*4. Streaming*

Streaming was assessed by one review whose studies were conducted in Australia (2) and the US (1) [25]. The primary studies were all moderate quality BA designs. Pooled results from these studies showed decreased ED LOS and waiting time. One primary Australian study examined the effect of streaming in the different triage categories and found improved ED LOS for lower acuity patients (14 and 18 minutes less for level 4 and 5 patients respectively) [25]. Although streaming had a positive effect on flow metrics, the review concluded that there was weak evidence to support its use [25].

*5. Fast Track*

Three reviews examined the effect of fast track on flow metrics [17, 21, 25]. Studies were conducted in the US (7), Canada (7), UK (5), Australia (5), and 1 each from New Zealand, Saudi Arabia, Turkey and Spain.

Pooled results from Oredsson et al. found that fast track reduced both ED LOS and waiting times [25]. These results for ED LOS were based on 7 moderate (2 RCT, 5 BA) and 3 low (BA) quality studies while those for waiting times were based on 6 moderate (1 RCT, 5BA) and 3 low (BA) quality studies. In Bond et al. 15 primary studies showed improved ED LOS and 8 showed improved waiting times [17]. The quality of these studies was not known. The results from Guo et al. also showed decreases in ED LOS and waiting times [21]. These were based on low (BA) quality primary studies. The Oredsson and Bond reviews concluded that there was moderate evidence to support the use of fast track [17, 25].

Three RCTs assessed the fast track intervention. Two were cluster RCT designs but there was no evidence to suggest that a cluster analysis was performed [S7, S8]. The third RCT was an individual level RCT that utilised appropriate statistical analyses but did not consider clustering in the analysis [S14].

6. *Triage*

The use of triage systems was assessed by one review with studies conducted in the US (3) and UK (2). The quality of these studies is not known. The results were mixed - 2 BA studies showed a decrease in waiting times while 3 studies (2CCT, 1 BA) showed an increase. The review concluded that the results were inconclusive [17].

7. *Diagnostic services*

Three reviews assessed diagnostic services which included point of care testing [17, 25] and advanced triage [21]. Point of care testing was evaluated in the US (3), UK (1) and Canada (1); all three reviews showed a reduction in ED LOS. The review by Oredsson et al. had three moderate (1 RCT, 2 BA) and two low (1 RCT, 1BA) quality primary studies and concluded that there was limited evidence to support use of point of care testing [25]. Guo et al. assessed advanced triage in one good quality cohort study, which showed a reduction in LOS [21].

Two individual level RCTs assessed point of care testing [S12, S13]. The statistical tests used were considered appropriate for the design but did not consider clustering/correlation of the data.

8. *Assessment and short stay units*

Three reviews examined assessment and short stay units [17-19]. Studies were conducted in the US (1), Canada (3), New Zealand (1) and Saudi Arabia (1). Short stay units showed a reduction in ED LOS for treat-and-release patients from a BA study [17]. Bullard et al. assessed rapid assessment zones and found

shorter ED LOS based on one RCT and BA study both rated as low quality [18]. The authors concluded that there was insufficient evidence to support rapid assessment zones [17, 18].

*9. Nurse directed interventions*

Nurse-directed interventions consisted of various interventions relating to nursing activities. Four reviews contributed to this category [19, 23, 25, 27]. The primary studies were conducted in Australia (8), UK (6) Canada (5), US (3), and 1 study each in New Zealand, Hong Kong, Singapore, Netherlands and Sweden.

Two systematic reviews from Jennings et al. [23] found that nurse practitioners led to shorter waiting times and LOS. Those findings were based on low quality studies and the authors concluded that the evidence was limited.

Rowe et al. [27] examined the impact of triage nurse ordering. The primary studies compared nurse initiated X-rays to ED physician initiated X-rays. The primary studies assessing the ED LOS were all weak (3 RCT, 1 CCT, 2 CC, 3 cohort and 3 BA). One RCT found a statistically significant reduction in ED LOS with triage nurse ordering [27]. Oredsson et al. looked at nurse requested X-rays and found a decrease in ED LOS/waiting times based on 3 RCTs [25]. The primary studies assessing ED LOS in Oredsson were moderate (1 RCT) and low (1 RCT) quality while those assessing waiting times were moderate (1 RCT) quality. The review concluded that evidence was limited [25].

Four of the primary studies assessing nurse directed interventions were RCTs. One utilized a cluster RCT design [S6] and three were individual level RCTs [S9-11]. There was no evidence to suggest that any of the RCTs performed an analysis that considered clustering/correlation.

*10. Physician directed interventions*

Physician directed interventions assessed the role of physicians in triage. Five reviews contributed to this category [16, 19, 24, 25, 26]. The study settings included the US (19), Australia (5), UK (3), Canada (3), Hong Kong (2) and one each in Northern Ireland, Jamaica, Sweden and Singapore.

Meta-analyses on triage liaison physician compared to nurse led triage showed statistically significant reductions in ED LOS [26]. These findings were based on 3 strong (1RCT, 2 CCT), 2 moderate (1ITS, 1 BA) and 14 (1RCT, 2CCT, 1 Cohort, 10 BA) weak quality primary studies. Two RCTs examining senior doctor triage found statistically significant decreases in ED LOS while one showed a statistically non-significant increase [16]. Meta-analyses also showed reductions in waiting times for senior doctor triage [16]. The results for ED LOS for senior doctor triage were based on 4 strong (3 RCT, 1 BA), 9 moderate (1 CCT, 2 cohort, 6 BA) and 6 weak (1 RCT, 1 cohort, 4 BA) quality primary studies. The results for waiting times were based on 1 strong (RCT), 5 moderate (2 cohort, 3 BA) and 7 weak (1 RCT, 1 cohort, 5 BA) quality studies. Although senior doctor triage showed improvements in flow metrics, the study concluded that the evidence was not strong enough [16].

Team triage was assessed by three reviews which all found decreased ED LOS and waiting times [24, 25, 26]. Ming et al. compared team triage to single nurse triage and found non-significant reductions in ED LOS in 4 RCTs which were all assessed as low quality [24]. Rowe et al. performed a sub-analysis on 4 non-RCT studies, comparing team triage and single physician triage and found a statistically significant reduction in ED LOS with team triage [26]. These results were based on weak quality primary studies (1 cohort, 3 BA). The primary studies from Oredsson et al. assessing ED LOS consisted of 3 moderate (1 RCT, 1 CCT, 1BA) and 1 low (RCT) quality. Those assessing waiting times from Oredsson et al. consisted of 1 moderate (BA) and 2 low (BA) studies. Ming et al. [24] and Oredsson et al. [25] both concluded that the evidence to support the use of team triage was limited.

Of the primary studies assessing physician directed interventions, five were RCTs. Four of the RCTs utilised a cluster randomised design that used appropriate cluster analyses considering clustering and correlation [S1-4]. The fifth RCT was a cluster randomised design but there was no evidence to suggest that a cluster analysis was performed [S5].

*11. Administrative and Organisational interventions*

Administrative and organizational interventions included a range of strategies such as increasing clinical and non-clinical staff numbers, increasing cubicles/treatment rooms, structural reorganization, implementation of coordinators [17, 21]. Studies were conducted in the US (7), Australia (3), Spain (2), Canada (2) and one each in Hong Kong, Israel, Sweden and Switzerland. Overall, there were improvements in ED LOS and waiting times. However, these results were based only on BA studies rated as either good or low quality in Guo et al [21]. The reviews concluded that there was insufficient evidence to support these interventions [17, 21].

*12. Miscellaneous*

Bond et al. assessed electronic tracking boards, dedicated ED radiology staff and bedside registration [17]. These studies were all US based BA designs; all three interventions reduced ED LOS, triage to treatment and triage to room times.

Table 3. Summary of effects of interventions

| Intervention (Author) | Outcome | Study design | No. of participants | Results |
|---|---|---|---|---|
| **Full capacity protocols** (Villa- Roel) | ED LOS | 1 BA | 61,329 | ED LOS decreased:18.9 vs13.9 hours, p<0.001(for all admitted patients) |
| **Computerised provider order entry** | ED LOS | Georgiou<br>3 BA<br><br>Bond<br>1 cohort, 2 BA | 52,501<br>(2 studies)<br><br>Not available | 2 studies each showed decreases and increases in ED LOS<br><br>2 studies (cohort, BA) showed decreased LOS;1 study showed increased LOS (BA) |
| | Other | Georgiou<br>3 BA | Not available | Decreased door to physician, physician to disposition decision, disposition decision to discharge times from 1 study |
| **Scribes** (Heaton) | ED LOS | 2 retrospective matched, 3 BA | 31,970<br>(4 studies) | No difference in ED LOS: MD -1.6 min, 95% CI [-22.3, 19.2] $I^2$ 87.62%, p<0.0001 |
| | Provider to disposition time | 1 retrospective matched, 2 BA | 25,543<br>(2 studies) | No difference: MD 18.8 min, (95% CI [-7.3, 44.6], $I^2$ 85.1%, p<0.0001 |
| | Number patients seen per hour | 1 prospective matched, 1 retrospective matched, 2 BA | 6878<br>(2 studies) | Increase: 0.17 more patients per hour , 95% CI [0.02, 0.32], $I^2$ 94.9%, p=0.000) |
| **Streaming** (Oredsson) | ED LOS | 2 BA | 141,017 | Median reduction in ED LOS of 9.5 minutes (min 0- max 11) |
| | Waiting time | 3 BA | 240, 429 | Median reduction in ED LOS of 31 minutes (min14-max 48 ) |
| **Fast Track** | ED LOS | Oredsson<br>2 RCT[a], 8 BA<br><br>Bond<br>1 RCT, 4 CCT, 5 cohort, 6 BA[b]<br><br>Guo<br>3 BA[c] | >100,000<br><br>Not available<br><br>Not available | Median reduction in ED LOS of 27 min (4 min-74 max)<br><br>15 studies showed improvement in ED LOS; 2 studies showed no difference<br><br>ED LOS decreased |
| | Waiting time | Oredsson<br>1 RCT[d], 8 BA<br><br>Bond<br>3 CCT, 1 cohort, 6 BA[e]<br>Guo<br>1 BA[c] | >90,000<br><br>Not available<br><br>Not available | Median reduction in waiting time of 24.5 min (2 min-51 max)<br><br>8 studies showed decreased waiting times; 1 study showed an increase<br><br>Decreased waiting times |
| **Triage** (Bond) | Waiting time | 3 BA, 2 CCT | Not available | Decreased waiting times in 2 BA; increased in 3 (2 CCT, 1 BA) |

MD= mean difference

[a] 2 RCT in Oredsson labelled CCT in Bond

[b] 2 of the 6 studies also in Oredsson for LOS

[c] same study in all 3 SR

[d] 1 RCT in Oredsson was labelled CCT in Bond

[e] 3 of the 6 studies also in Oredsson

Table 3 continued

| Intervention (Author) | Outcome | Study design | No. of participants | Results |
|---|---|---|---|---|
| **Diagnostic services** | | | | |
| Point of care testing | ED LOS | Oredsson<br>2 RCT, 3 BA<br><br>Bond<br>1 RCT, 1 BA<br><br>Guo<br>1 RCT[f], 1BA[f] | 18,401<br><br>Not available<br><br>Not available | Median reduction in ED LOS of 21 min (-8 min-54 max)<br><br>ED LOS decreased<br><br>ED LOS decreased |
| Advanced Triage | ED LOS | Guo<br>1 Cohort | Not available | ED LOS decreased |
| **Assessment and short stay units** | | | | |
| Rapid assessment zones/pods (Bullard) | ED LOS | 1 RCT, 1 CCT, 1 BA | 22,989 | ED LOS decreased<br>RCT : MD -20 min, 95% CI [-47.2, 7.2]<br>BA: MD -192 min, 95% CI[ -211.6, -172.4]<br><br>Acuity level 5<br>RCT :MD -34 min, 95% CI [-68.6, 0.6]<br>CCT :MD -20 min, 95% CI [-23.1, -16.9] |
| | Physician initial assessment | 1 RCT, 1 CCT, 2 BA | 18,722 | Physician initial assessment time decreased<br>RCT: MD -8.0 min, 95% CI [-13.8, -2.2]<br>BA: MD -33 min, 95% CI [-42.3, -23.6]<br>BA: MD -18 min, 95% CI [-22, -13.8]<br><br>Acuity level 5<br>RCT: MD -14 min, 95% CI [-33.5,5.5]<br>CCT: MD - 11.1 min, 95%CI [-12.4, -9.8] |
| Short stay unit (Bond) | ED LOS | 1 BA | Not available | Decreased for treat and release patients |
| Medical assessment unit (Elder) | Other | 1 retrospective cohort | 894 | Mean time from medical assessment to decision : 170.2 minutes |

MD= mean difference
[f] same studies seen in Bond and Oredsson

Table 4. Summary of findings for nurse directed interventions

| Intervention | Outcome | Study design | No. of participants | Results |
|---|---|---|---|---|
| **Nurse directed** | | | | |
| Nurse practitioners (Jennings) | ED LOS | 1 cohort, 2 descriptive, 2 audit, 1 case series, 1 case control | 32,419 | ED LOS decreased in 5 studies; 3 studies showed no difference |
| | Waiting time | 1 RCT, 1 cohort, 2 audit, 1 descriptive, 1 case series, 1 case control, 1 BA | 9,592 | Waiting time decreased in 5 studies; 4 studies showed no difference |
| Nurse practitioners/ Clinical Initiative Nurse (Elder) | ED LOS | 1 RCT, 2 cohort, 1 BA, 1 case control | 22,331 (4 studies) | ED LOS decreased in 4 studies; 1 study showed no difference |
| | Waiting time | 1 RCT, 2 cohort, 1 case control, 1BA | 23,933 | Waiting time decreased in 4 studies; 1 study showed no difference |
| Triage nurse ordering (Rowe) | ED LOS<br><br><br><br>ED LOS (patients with fractures)<br><br><br>ED LOS (patients with no fractures) | 3 RCT, 1CCT, 3 cohort, 3 BA, 2 case control | 22,084 | <u>ED LOS decreased</u><br>1 RCT: MD -37.2 min, 95% CI [ -44.1, 30.3], p<0.00001<br>3 non- RCT: MD -50.9min, 95% CI [-56.3, -45.5]; $I^2$ 92%, p<0.00001<br><br>3 RCT: MD -20 min, 95% CI [-37.48, -1.91]; $I^2$ 92%, p=0.03<br>5 non-RCT: MD -18.2 min, 95% CI [-23.2, -13.2]; $I^2$ 28%, p<0.00001<br><br>2 RCT: MD 0.9 min 3, 95%CI [-5.44, 7.31];$I^2$ 0%, p=0.77<br>2 non-RCT: MD -33 min, 95% CI [-71.13, 3.26]; $I^2$ 94%, p=0.07 |
| | Physician initial assessment time | 2 RCT, 1 cohort | 4141 | <u>Physician initial assessment time decreased</u><br>2 RCT: MD -3.0, 95% CI [-6.9, 0.9], $I^2$ 0%, p =0.14<br>Cohort: 10 minute reduction |
| Nurse initiated x-rays (Oredsson) | ED LOS/Waiting time | 3 RCT | 2,682 | Median reduction of 10 min (min 6-37 max) |

MD- mean difference

Table 5. Summary of findings for physician directed interventions

| Intervention | Outcome | Study design | No. of participants | Results |
|---|---|---|---|---|
| **Physician directed** | | | | |
| Physician assisted triage (Elder) | ED LOS | 1 RCT, 3 BA | 64,815 | ED LOS decreased in 1 RCT and 3 BA |
| | Waiting time | 2 CCT, 1BA | 24,545 | Waiting time decreased in 1 CCT and 1 BA studies; no result for 1 CCT |
| Triage liaison physician (Rowe) | ED LOS | 2 RCT, 4CCT, 11 BA, 1 ITS, 1 cohort | 367,828 (13 studies) | ED LOS decreased in 2 RCT: MD -36.8, 95% CI [-51.1, -22.8], $I^2$ 0%, p<0.00001 |
| | Physician initial assessment | 1 RCT, 2 CCT, 6 BA | 171,185 (7 studies) | Physician initial assessment time decreased<br>1 RCT: MD -30 min, 95% CI [-56.9, -3.0]<br>8 non-RCT: median absolute improvement -19 min (IQR -26 to -11) |
| Senior doctor triage (Abdulwahid) | ED LOS | 4 RCT, 1CCT, 3 cohort,11 BA | 605, 931 | ED LOS decreased RCT 1: MD -122, 95% CI [-133.38, -110.62]<br>RCT 2: MD -36, 95% CI [ -50.97, -21.03]<br>RCT 3: MD -45, 95% CI [-91.48, 1.48]<br>ED LOS increased RCT 4: MD 6, 95% CI [-11.58 , 23.58]<br>12 Non- RCT: median decrease in ED LOS of -26 min (IQR -6 to-56) |
| | Waiting time | 2 RCT, 3 cohort, 8 BA | 275,254 | Waiting time decreased<br>2 RCT: MD -26.1, 95% CI [-31.6, -20.6], $I^2$ 0%, p<0.00001<br>11 Non- RCT: median decrease in waiting time of -15 min (IQR -7.5 to -18) |
| Team triage | ED LOS | Rowe<br>1 cohort, 3BA<br><br>Oredsson<br>2 RCT[a], 1 CCT, 1 BA<br><br>Ming<br>4 RCT | 82, 297 (3 studies)<br><br>29,674<br><br>14,772 | ED LOS decreased<br>4 non-RCT : MD-22.7, 95% CI [-24.3, -21.0], $I^2$ 0%, p<0.00001<br>13 non-RCT: median absolute improvement -36 min (IQR -46 to 21min)<br><br>Median reduction in ED LOS of 40.5 minutes (min 0- max 55)<br><br>ED LOS decreased<br>RCT 1:MD -24 min, p=0.005; RCT 2:MD -36 min, p=0.001<br>RCT 3:MD -21 min, p=0.168; RCT 4:MD -45 min, p= 0.057<br>MD= median difference |
| | Waiting time | Oredsson<br>3BA<br>Ming<br>2 RCT | 25,927<br><br>7,328 | Median reduction of 18 minutes (min 16- max 20)<br><br>Waiting time decreased : RCT 1: MD -26 min, p<0.001;RCT 2: MD-30 min, p=0.029<br>MD= median difference |

MD= Mean difference [a] same RCT in Ming

Table 6. Summary of findings for administrative/organizational and miscellaneous interventions

| Intervention | Outcome | Study design | No. of participants | Results |
|---|---|---|---|---|
| **Administrative/organizational interventions** | | | | |
| Multifaceted (Bond) | ED LOS | 7 BA | Not available | 7 studies showed decreased ED LOS; 1 showed increase |
| | Waiting time | 3 BA | Not available | Decreased waiting times in all |
| Staffing changes (Bond) | ED LOS | 4 BA | Not available | ED LOS decreased in 3 studies; no difference in 1study |
| | Waiting time | 5 BA | Not available | Decreased waiting time in 5 studies; 1 reported increase for urgent cases |
| ED staffing/reorganization (Guo) | ED LOS | 1 cohort, 2 BA | Not available | ED LOS decreased |
| | Waiting time | 2 BA | Not available | Waiting time decreased |
| System-wide interventions (Guo) | ED LOS | 1BA | Not available | Decreased ED LOS with a mean 27 minutes pre versus 22 minutes post intervention ($p<0.001$) |
| | Other | 1BA | Not available | Time from arrival to exam room: 27 minutes pre versus 22 minutes post ($p <0.001$)<br><br>Time from exam room to physician: mean 20 pre versus 18 post ($p<0.001$)<br><br>Time from physician evaluation to discharge: mean 100 minutes pre versus 99 minutes post ($p=.33$) |
| **Miscellaneous interventions** (Bond) | | | | |
| Electronic tracking board | ED LOS | 1BA | Not available | ED LOS decreased |
| Dedicated ED radiology staff | ED LOS | 1BA | Not available | ED LOS decreased |
| Bedside registration | Other | 1BA | Not available | Time from triage to room decreased<br>No effect on mean time from room to disposition |

## DISCUSSION

This umbrella review summarised evidence from systematic reviews and meta-analyses on interventions that improve ED patient flow. Overall, the evidence supporting the effectiveness of the interventions was weak (as reported by the systematic review authors). Only one intervention had moderate evidence to support its use- fast track. However, one review author noted that, although the evidence was sufficient, there were other factors such as physical limitations in the ED, limited human resources and cost-effectiveness that could affect the implementation of fast track [17].

The interventions were not standardised with different terms possibly representing the same intervention. For example, Oredsson et al. [25] examined nurse requested x-rays, an activity performed by nurse practitioners [19, 23] and seen in triage nurse ordering [27]. In some instances, the same primary studies provided evidence for a range of interventions as seen with senior doctor triage, triage liaison physician, physician assisted triage and team triage [16, 19, 24, 25, 26]. Reviews that included paediatric settings did not differentiate between adult and paediatric EDs to determine if this affected the intervention effect. The heterogeneity in the intervention and control groups could affect how interventions were implemented in different settings, a factor which may affect the ability to generalise findings.

Another potential factor limiting generalisability was the overlap of interventions. The multifaceted interventions were based on the implementation of combined strategies. Since no direct comparisons were made between the single intervention and the combination of strategies it is unknown which one was responsible for the observed effects. This was also a factor in fast track, which in some studies was either nurse or doctor led and in others was combined with streaming or rapid assessment zones [17, 25]. Again it is unclear which factor (nurse led or doctor led fast track, streaming or assessment zones) contributed to the effect.

A 2011 overview examined interventions to mitigate ED crowding [31]. Although the overview did not meet criteria for inclusion in the umbrella review, it did measure flow metrics and identified additional

interventions that are worth mentioning. These included bedside ultrasound, computerisation, clinical decision and observation units, bed coordination and multifaceted interventions (Eg. UK 4 hour target). These interventions also showed benefits to improving flow metrics but like the interventions identified in the umbrella review, there was still insufficient evidence to support the implementation of any of the interventions [31].

Although this umbrella review identified interventions that could improve patient flow, an understanding of how and why these interventions produced (or did not produce) their desired effect, is still unclear. This is important because the studies were conducted in countries with different models of emergency care. The majority of studies were in countries with developed emergency care systems and a dedicated emergency medicine specialty (US, UK, Australia, Canada). Thus, generalising the findings to other models of ED care may still be difficult; an exploration of the mechanism underlying the intervention or the patient flow process may be beneficial.

Lastly, the uncertainty surrounding the appropriate use of statistical tests in the cluster RCTs affects the conclusions drawn on the effectiveness of the intervention. The RCTs using individual patient designs appeared to utilize appropriate tests; however, the potential importance of clustering/correlation in individual patient RCTs is an issue that should be considered in future trials of patient flow [32]. This is particularly important for the fast track intervention which was the only intervention with evidence supporting its implementation but for whom clustering/correlation was not considered in the RCTs that examined the intervention.

**Limitations**

There are several limitations to this review. Measures of patient flow were not standardized across the included systematic reviews. The most common outcome measures were ED length of stay and waiting times. Two primary studies from one review presented different definitions of ED LOS (arrival to

physical departure versus triage to physical departure). This was not unexpected since there isn't a universal definition for patient flow and crowding terms and measures.

Although the majority of the systematic reviews were graded as either high or moderate quality, within the systematic reviews there was a predominance of weak primary studies and study designs. Many of the systematic review findings were based on primary studies with non- RCT designs; almost two-thirds were before-after studies, which are known to produce bias [33]. The Cochrane EPOC guidance recommends against the inclusion of uncontrolled before-after study designs in systematic reviews [33].

Some systematic review findings were based on a small number of primary studies and several reviews included abstracts rather than peer-reviewed full text articles. Some systematic reviews examining the same intervention had overlap of the primary studies contributing to the outcome measure. Thus it was not always new evidence being presented for each intervention.

The authors of the systematic reviews also noted the high heterogeneity seen with study settings, designs, populations, interventions and outcome measures which prevented the pooling of results and performance of meta-analyses.

**Conclusion**

The evidence to support implementation of the majority of the interventions was considered weak. Future studies should distinguish between non-flow (crowding) and flow and the respective measures. Stronger study designs are also required, as well as an exploration of the patient flow process, how these interventions work and why some interventions work in some settings and not others. Furthermore, the issue of correlation of observations when conducting statistical analyses should be considered in all future studies. ED patient flow is a complex phenomenon and a greater understanding of the patient flow process could assist in the development of effective interventions.

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Figure 1. PRISMA flowchart of study selection

**REFERENCES**


1. Asplin B. Measuring crowding: time for a paradigm shift. *Acad Emerg Med* [online]. 2008;3(4):459-461. Available from: http://onlinelibrary.wiley.com/doi/10.1197/j.aem.2006.01.004/pdf. (Accessed 2017 Aug10).

2. Damelio R. Thinking about work. In: Damelio R, editor. The basics of process mapping. NY: CRC Press; 2007. p. 21-30.

3. NHS Institute for Innovation and Improvement. Quality and Service Improvement Tools. Patient flow [online]. UK: NHS Improving Quality; 2006-2013. Available from: http://webarchive.nationalarchives.gov.uk/20110927032647/http://www.institute.nhs.uk/quality_and_service_improvement_tools/quality_and_service_improvement_tools/patient_flow.html (Accessed 2017 Sep 1)

4. Service Design and Delivery Committee. Tackling emergency department crowding [online]. London: The Royal College of Emergency Medicine; 2015. Available from: https://portal.rcem.ac.uk/LIVE/docs/College%20Guidelines/5z23.%20ED%20crowding%20overview%20and%20toolkit%20(Dec%202015).pdf (Accessed 2017 Aug10)

5. Hwang U, McCarthy ML, Aronsky D et al. Measures of crowding in the emergency department: a systematic review. *Acad Emerg Med* [online]. 201;18(5):527-538. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21569171. (Accessed 2017 Aug 10)

6. NHS Digital. Hospital episodes statistics [online]; Leeds (UK): NHS Digital; 2018. Available from: http://content.digital.nhs.uk/hes (Accessed 2018 Jan 19).

7. Centre for disease control and prevention. Ambulatory health care data [online]. Atlanta (USA): Centre for Disease Control and Prevention; 2017. Available from: https://www.cdc.gov/nchs/ahcd/index.htm (Accessed 2018 Jan 19).

8. Lui S, Hobgood C, Brice JH. Impact of critical bed status on emergency department patient flow and overcrowding. Academic Emergency Medicine [online]. 2003; 10 (4): 382-5. Available from: http://www.ncbi.nlm.nih.gov/pubmed/12670854. (Accessed 2016 August 10).

9. Becker LA, Oxman AD. Chapter 22: Overviews of reviews. In: Higgins JPT, Green S (editors), *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0 (updated March 2011). The Cochrane Collaboration, 2011. Available from www.handbook.cochrane.org.

10. The Joanna Briggs Institute. Joanna Briggs Institute Reviewer's Manual: 2014 edition/supplement. *Methodology for JBI Umbrella Reviews* [online]. The Joanna Briggs Institute: South Australia; 2014. Available from: http://joannabriggs.org/assets/docs/sumari/reviewersmanual-2014.pdf (Accessed 2017 Aug10).

11. Grant MJ, Booth A. Typology of reviews: an analysis of 14 review types and associated methodologies. *Health Info Libr J* [online]. 2009;26(2):91-108. Available from: https://www.ncbi.nlm.nih.gov/pubmed/19490148 (Accessed Aug 12)

12. Lee E, Dobbins M, Decorby K et al. An optimal search filter for retrieving systematic reviews and meta-analyses. *BMC Med Res Methodol* [online]. 2012;12:51. Available from: http://bmcmedresmethodol.biomedcentral.com/articles/10.1186/1471-2288-12-51 (Accessed 2017 Aug 25).

13. Lunny C, McKenzie JE, McDonald S. Retrieval of overviews of systematic reviews in MEDLINE was improved by the development of an objectively derived and validated search strategy. *J Clin*

*Epidemiol* [online]. 2016;74: 07-118. Available from: http://www.jclinepi.com/article/S0895-4356(15)00578-8/pdf (Accessed 2017 Aug 25).

14. Shea BJ, Reeves BC, Wells G et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised and non-randomised studies of healthcare interventions or both. *BMJ* [online]. 2017;358. Available from: http://www.bmj.com/content/358/bmj.j4008 (Accessed 2018 Jan 25).

15. PRISMA. PRISMA Transparent reporting of systematic reviews and meta-analyses [online]. 2015. PRISMA. Available from: http://prisma-statement.org/PRISMAStatement/FlowDiagram.aspx (Accessed 2017 Aug16).

16. Abdulwahid M, Booth A, Kuczawski M et al. The impact of senior doctor assessment at triage on emergency department performance measures: systematic review and meta-analysis of comparative studies. *Emerg Med J* [online]. 2016;33:504-513. Available from: http://emj.bmj.com/content/early/2015/07/16/emermed-2014-204388 (Accessed 2017 Aug21).

17. Bond K, Ospina M, Blitz S et al. Interventions to reduce overcrowding in emergency departments. Ottawa: Canadian Agency for Drugs and Technologies in Health (CADTH). Technology Report Issue 67.4. 2006. Available from: https://www.cadth.ca/media/pdf/320d_overcrowding_tr_e_no-appendices.pdf (Accessed 2017 Aug22)

18. Bullard MJ, Villa-Roel C, Guo X et al. The role of a rapid assessment zone/pod on reducing overcrowding in emergency departments: a systematic review. *Emerg Med J* [online]. 2012;29(5):372-8. Available from: https://www.ncbi.nlm.nih.gov/pubmedhealth/PMH0046922/ (Accessed 2017 Aug 21).

19. Elder E, Johnston AN, Crilly J. Systematic review of three key strategies designed to improve patient flow through the emergency department. *Emerg Med Australas* [online]. 2015;27(5):394-404. http://onlinelibrary.wiley.com/doi/10.1111/1742-6723.12446/abstract (Accessed 2017 Aug21).

20. Georgiou A, Prgomet M, Paoloni R et al. The effect of computerized provider order entry systems on clinical care and work processes in emergency departments: a systematic review of the quantitative literature. *Ann Emerg Med* [online]. 2013;61(6):644-53.e16. Available from: http://www.annemergmed.com/article/S0196-0644(13)00100-5/abstract (Accessed 2017 Aug 21).

21. Guo B, Harstall C. Strategies to reduce emergency department overcrowding. Edmonton, AB, Canada: Alberta Heritage Foundation for Medical Research. Health Technology Assessment; 38. 2006. Available from: http://www.ihe.ca/hta/publications.html?Category=HTA%20Series%20A (Accessed 2017 Aug 21).

22. Heaton HA, Nestler DM, Lohse CM et al. Impact of scribes on emergency department patient throughput one year after implementation. *Am J Emerg Med* [online]. 2016;33:2-18-2028. Available from: http://www.ajemjournal.com/article/S0735-6757(16)30826-9/pdf (Accessed 2017 Aug 21).

23. Jennings N, Clifford S, Fox AR et al. The impact of nurse practitioner services on cost, quality of care, satisfaction and waiting times in the emergency department: A systematic review. *Int J Nurs Stud* [online]. 2015;52(1):421-435. Available from: http://www.journalofnursingstudies.com/article/S0020-7489(14)00176-X/pdf (Accessed 2017 Aug 21).

24. Ming T, Lai A, Lau PM. Can Team Triage Improve Patient Flow in the Emergency Department? A Systematic Review and Meta-Analysis. *Adv Emerg Nurs J* [online]. 2016; 38(3):233-350. Available from: https://www.ncbi.nlm.nih.gov/pubmed/27482995 (Accessed 2017 Aug 21)

25. Oredsson S, Jonsson H, Rognes J et al. A systematic review of triage-related interventions to improve patient flow in emergency departments. *Scand J Trauma, Resusc Emerg Med* [online]. 2011;19:43. Available from S,: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3152510/ (Accessed 2017 Aug 21)

26. Rowe BH, Guo X, Villa-Roel C et al. The role of triage liaison physicians on mitigating overcrowding in emergency departments: a systematic review. *Acad Emerg Med* [online]. 2011a; 18(2):[111-20 pp.]. Available from: http://onlinelibrary.wiley.com/o/cochrane/cldare/articles/DARE-12011001679/frame.html (Accessed 2017 Aug 21)

27. Rowe BH, Villa-Roel C, Guo X et al. The role of triage nurse ordering on mitigating overcrowding in emergency departments: a systematic review. *Acad Emerg Med* [online]. 2011b; 18(12):1349-57 pp. Available from: http://onlinelibrary.wiley.com/o/cochrane/cldare/articles/DARE-12012000322/frame.html. (Accessed 2017 Aug 21).

28. Villa-Roel C, Guo X, Holroyd BR et al. The role of full capacity protocols on mitigating overcrowding in EDs. *Am J Emerg Med* [online]. 2012;30(3):412-20. Available from: https://www.ncbi.nlm.nih.gov/pubmed/21367554 (Accessed 2017 Aug 21).

29. Goodacre S. Appropriate analysis and reporting of cluster randomized trials. *Emerg Med J* [online]. 2005;22(2):156. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1726679 (Accessed 2017 Sept 14)

30. Weber E. Correlation and crowding measures: the fundamental lesson behind complex statistics. *Emerg Med J* [online]. 2016;33:306. Available from: http://escholarship.org/uc/item/7qv067v7#page-1 (Accessed 2017 Sept14)

31. de Grood J, Bota M, Villa-Roel C et al. Overview of Interventions to Mitigate Emergency Department Overcrowding. HQCA, Calgary, AB. December 2011: 247-321.

32. Kahan BC, Morris TP. Assessing potential sources of clustering in individually randomised trials. BMC Medical Research Methodology [online].2013; 13:58. Available from: https://bmcmedresmethodol.biomedcentral.com/articles/10.1186/1471-2288-13-58 (Accessed 2017 Oct 2)

33. Goodacre S. Uncontrolled before - after studies: discouraged by Cochrane and EMJ. *Emerg Med J* [online]. 2015; 32(7):507-508. Available from: http://eprints.whiterose.ac.uk/88476/3/WRRO_88476.pdf (Accessed 2017 Sept13)