AUSTRALASIAN JOURNAL OF PARAMEDICINE

PARAMEDICS AUSTRALASIA

Review

Is age associated with emergency medical service transport to a trauma centre in patients with major trauma? A systematic review

Elizabeth Brown BSc(Hons), MSc, PhD, is a paramedic[1,2]; Hideo Tohira PhD, MD, MEng, MPH, FJAAM is Research Fellow[1,3]; Paul Bailey MBBS, FACEM, PhD is Associate Professor[1] and Medical Director[2,4]; Judith Finn PhD, is Director[1] and Adjunct Research Professor[2]

Affiliations:
[1]Prehospital Resuscitation and Emergency Care Research Unit, School of Nursing, Midwifery and Paramedicine, Curtin University, Western Australia
[2]St John Ambulance, Western Australia
[3]Division of Emergency Medicine, The University of Western Australia, Perth, Western Australia
[4]Emergency Department, St John of God Murdoch Hospital, Perth, Western Australia
[5]School of Public Health and Preventive Medicine, Monash University, Melbourne, Victoria

https://doi.org/10.33151/ajp.17.742

Abstract

Introduction
Older adults with major trauma are known to have higher mortality rates than their younger counterparts and there is a known survival benefit of treatment in trauma centres. This systematic review sought to answer the question: are older patients with major trauma more or less likely to be transported to a trauma centre by emergency medical services (EMS) than younger patients?

Methods
The following databases were searched: Ovid MEDLINE, Ovid EMBASE, EBSCO CINAHL, Scopus, Cochrane Library and grey literature until 7 March 2019. Studies meeting each of the following criteria were included: 1) comparative study, including randomised controlled trials, cohort studies, cross-sectional studies, case-control studies; 2) study participants must be patients with major trauma; 3) the patients must have been initially transported from the accident scene to hospital by EMS, and 4) the study must report the association between major trauma patient, age and trauma centre transport.

Results
We identified 3365 unique citations and one study was identified through other sources. In total, 17 studies were included. The studies defined major trauma patients either by the meeting of pre-hospital trauma triage criteria or a retrospective diagnosis. All of the included studies reported that older age was associated with a reduced likelihood of EMS trauma centre transport when compared to younger age in major trauma patients.

Conclusion
The studies included in this review all showed that older age is associated with a reduced likelihood of EMS trauma centre transport when compared to younger age in major trauma patients.

Keywords:
older adults; major trauma; trauma center; trauma centre; EMS

Corresponding Author: Elizabeth Brown, elizabeth.e.brown@postgrad.curtin.edu.au

Introduction

In both developed and developing countries, injury is known to be a significant cause of morbidity and mortality (1,2). Major trauma has traditionally been perceived as being a disease of the young (3). However, over recent years the mean age of patients with major trauma has increased (3) and older adults with major trauma are known to have higher mortality rates than their younger counterparts (4).

Emergency medical services (EMS) are often the first point of medical care for patients with trauma, with the prevention of further injury, initiation of resuscitation and timely transport to an appropriate hospital facility the key objectives of this care (5,6). The survival benefit of trauma centre (TC) care is well documented (7,8) and this survival benefit has also been shown to be present in older adults with major trauma (9,10). Despite this, it is suggested that older patients with major trauma are less likely to be transported by EMS to specialised trauma services (under triaged) (11-13). This systematic review sought to answer the question of whether older patients with major trauma are more or less likely to be transported to a TC by EMS than younger patients.

Methods

Protocol and registration
The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement was followed for this systematic review and meta-analysis (14). Details of the protocol for this systematic review were registered on PROSPERO (CRD42018115532) and can be accessed at www.crd.york.ac.uk/PROSPERO

Eligibility criteria
To be included in this review, studies needed to meet all of the following criteria: 1) be a comparative study, including randomised control trials, cohort studies, cross-sectional studies, case-control studies; 2) study participants must be patients with major trauma; 3) the patients must have been initially transported from the accident scene to hospital by EMS, and 4) the study must report the association between major trauma patient age and TC transport. We excluded reviews, letters, editorials, case studies and all other commentaries. The literature search was not limited by language or publication date.

Information sources
To identify studies eligible for review, computerised searches of bibliographic databases were performed. We searched Ovid MEDLINE, Ovid EMBASE, EBSCO CINAHL, Scopus, Cochrane Library and grey literature via Mednar until 7 March 2019.

Search strategy
Our search strategy involved three key concepts: 1) major trauma 2) age and 3) EMS transport to a TC (Table 1). Terms were mapped to the appropriate MeSH/EMTREE subject headings and 'exploded'. Keywords relating to these three concepts were combined with the boolean operator 'AND'. We used review articles to find other relevant articles and identified additional sources through the article reference lists.

Table 1. Search strategy (Medline)

#	Medline terms	Results
1	(Major trauma or injury severity score or traum* or injur*).mp	1,27,624
2	(multiple trauma or "wounds and injuries" or injury severity score).sh	93,892
3	1 or 2	1,27,624
4	(older adult or older age or elderly or advanc* age or old* or age*).mp	11,116,811
5	(aged or adult).sh	5,826,220
6	4 or 5	11,116,811
7	(young*).mp	1,233,006
8	(young adult or middle aged).sh	4,302,937
9	7 or 8	4,734,633
10	(emergency medical service* or paramedic* or ambulance* or transport* or pre hospital or prehospital or pre-hospital or emergency medical technician).mp	742,110
11	(emergency medical services or ambulances or emergency health service or emergency service, hospital).sh	99,432
12	10 or 11	796,169
13	(trauma centre or trauma center or trauma cent* or trauma unit or hospital or accident and emergency or emergency department or casualty).mp	125,051
14	(trauma centers or trauma unit).sh	9354
15	13 or 14	131,281
16	(triage or triage protocol* or protocol* or triage guideline* or guideline* field triage or field medicine or undertriage OR under?triage).mp	532,232
17	(triage or "transportation of patients").sh	18,735
18	16 or 17	540,297
19	3 and 6 and 9 and 12 and 15 and 18	1263
20	Limit to humans	1249

Study selection
To select potentially relevant papers, EB performed the database search and conducted a review based on title and abstract to identify potentially relevant studies. Full-text articles were obtained if the abstract contained relevant information or if

more information was required to inform inclusion or exclusion. To ensure the eligibility criteria were met, included studies were then independently assessed by EB and HT. Discrepancies were resolved by consensus. As the authors of this systematic review are the authors of one of the studies included in the review (10), an independent person assessed that study to ensure the eligibility criteria were met.

Data collection process and data items

Descriptive, methodological and outcome data were extracted from the included studies using a pre-determined electronic spreadsheet developed by EB. Data extracted included the year of publication, research design, sample size, the population of interest, predictor and outcome measures. EB extracted information and double-checked the accuracy and details of the data.

Risk of bias in individual studies

The checklist developed by GRADE for methodological assessment of observational studies (which can be found in Table 5.5 of the GRADE handbook) was used to assess the methodological quality of studies included in this systematic review (15). Results were collated and accuracy independently checked by two authors (EB and HT). The consensus was reached by discussion. As the authors of this review are the authors of one of the studies included in this review (10) the risk of bias for this study was undertaken by an independent person.

Summary measures

Odds ratios (OR) were used to compare the likelihood of EMS transport to a TC between younger and older major trauma patients. Crude OR were calculated for studies that provided numbers of patients transported and not transported by EMS to a TC and their ages. When the raw number of patients, their ages and/or their transport destination were not available then these numbers were calculated from the available data. If the extraction of raw numbers was not possible from the data in the paper, the study authors were contacted for further information. If no response was received the findings were only included in the descriptive summation of results.

Statistical analysis and synthesis of results

The outcome of interest was transport to a TC by EMS in patients with major trauma. The likelihood of EMS TC transport in younger and older major trauma patients was compared using odds ratios (OR) and 95% confidence intervals (95% CI). Statistical heterogeneity between studies was assessed using the I^2 statistic and we applied the rule that results would not be pooled if I^2 exceeded 50% (high heterogeneity) (16). Results were summarised by forest plots of the OR if two or more studies reported data for older and younger age groups. RevMan Version 5.3.5. was used to create the Forest plots (17) and funnel plots were examined for publication bias.

Results

Study selection

Our search strategy yielded 3365 unique citations and one study was identified through other sources (a study that was undertaken by ourselves and had been accepted for publication) (10). EB screened the titles and abstracts, identifying 20 potentially relevant articles (10-12,18-34). The full text of these articles was then reviewed by EB and HT for eligibility according to the inclusion criteria. We excluded three studies, the first because only patients over 55 years of age were included with no comparison age, the second because major trauma was not defined and patients with trauma of all severities were included, and the third as the outcome was not transport to a TC, but sustaining major trauma. In total, 17 studies met the selection criteria and were included in the systematic review.

Study characteristics

The characteristics of the included studies are summarised in Table 2. All studies were retrospective with the majority being retrospective cohort studies. To define major trauma, five studies used a pre-hospital trauma triage criteria, 11 studies used a retrospective major trauma diagnosis and one study used death in the emergency department (ED). The majority of studies were undertaken in the United States, three were undertaken in Australia and one in Canada.

Risk of bias within studies

Bias was assessed using the checklist developed by GRADE for observational studies (Table 5.5 of the GRADE handbook) (15). All studies were judged as having a high risk of confounding as it would not be possible to control for all factors that may affect the EMS providers' transport decision. No study was excluded for its methodological quality.

Results of individual studies

The results of the individual studies will be reported under the specific criterion that the study used to define major trauma. Additional data were requested from nine authors and responses were received from two authors.

Pre-hospital trauma triage criteria

A total of five studies used the meeting of a pre-hospital trauma triage criteria (PTTC) to define major trauma. Of these, four compared the likelihood of TC transport between older and younger patients (11,19,22,29) and one study compared the likelihood of trauma centre transport between major trauma patients and non-trauma patients (21). The four studies that used the meeting of a PTTC to define major trauma, all reported a reduced likelihood of TC transport in older patients with major trauma compared to younger patients (11,19,22,29). The pooled estimate from these four studies showed a decreased odds of EMS TC transport in older patients with

Table 2. Characteristics of included studies

Study	Country	Study design	Sample size	Population	Exclusion	Exposure	Comparison	Outcome
Baez et al (2003)	US	Retrospective cross-sectional	1068	Patients ≥18yrs who met at least one criterion from Step 1 or Step 2 of ACSTTC and ISS >15	Patients with poisoning; single-system burns; late effects of injuries	Not defined	Not defined	EMS transport to Level I or Level II TC, or non-TC
Brown et al (2019)	Australia	Retrospective cohort	1625	Patients ≥16yrs and ISS >15	Patients with poisoning; drowning; hanging; late effects of injury	Age ≥65yrs	Age 16-64yrs	EMS transport to Level I TC, or non-TC
Chang et al (2008)	US	Retrospective cohort	26,565	Patients who met ACSTTC for physiology, injury pattern and mechanism of injury who were declared priority 1 status by EMS personnel	Patients being transferred between hospitals	Age ≥65yrs	Age <65yrs	EMS transport to Level I, Level II or Level III TC, or non-TC
Cox et al (2014)	Australia	Retrospective cohort	60,751 (7461 retrospectively confirmed as major trauma)	Patients ≥16yrs who met a trauma triage criteria then retrospectively defined as major trauma if they had one or more of the following: ISS >12, ICU admission with mechanical ventilation >24hrs or urgent surgery	Patients with injuries secondary to a non-traumatic cause	Age >55yrs	Age 16-55yrs	EMS transport to major trauma service equivalent to Level I TC, or non-TC
Davis et al (2012)	US	Retrospective cohort	2051	Patients ≥15yrs with an injury-related diagnosis or an emergency classified admission then defined as meeting a trauma triage criteria or retrospectively defined as major trauma if ISS ≥16	No exclusions	Age ≥55yrs	Age 15-54yrs	EMS transport to Level II TC, or non-TC
Doumouras et al (2012)	Canada	Retrospective cohort	898	Patients ≥16yrs who met physiologic Toronto Field Trauma Triage Criteria	Patients with burns; drowning; suffocation; electric shock; poisoning; non-mechanical causes of injury. Patients for whom TC was nearest hospital	Age ≥65yrs	Age 16-64yrs	EMS transport to Level I, or non-TC. Excluding patients for whom TC was nearest hospital

Table 2. Characteristics of included studies (continued)

Study	Country	Study design	Sample size	Population	Exclusion	Exposure	Comparison	Outcome
Fitzharris et al (2012)	Australia	Retrospective cohort	9344	Patients of all ages who met one or more physiologic, anatomic or mechanism trauma triage criteria	Patients who refused treatment; were only assisted; transported by air; dead on examination; recorded as 'other'; inter-hospital transfers	Age ≥50yrs	Age <50yrs	EMS transport to major or regional TC, or non-TC
Flottemesch et al (2016)	US	Retrospective cohort	140,766	Patients ≥18yrs with head injury AIS ≥4	Patients being transferred from other acute care hospitals and patients initially treated at Level III TC	Age 45-64yrs, 65-84yrs, ≥85yrs	Age 18-44yrs	Initial treatment at Level I or Level II TC, or initial treatment at Level IV or V TC
Garwe et al (2017)	US	Retrospective cohort	84,930	Patients ≥17yrs who met Oklahoma's major trauma definition	Patients who died at scene; had overexertion injuries; submersions; poisonings; asphyxiation; injuries caused by pre-existing conditions (eg. osteoporosis)	Age ≥55yrs	Age 17-55yrs	EMS transport to Level I or Level II TC, or non-TC
Holst et al (2016)	US	Retrospective cohort	3971	Patients ≥18yrs with trauma related ED visit defined by the injury variable in the National Emergency Department Sample, which resulted in death in ED	No exclusions stated	Age 35-49yrs, 50-64yrs, ≥65yrs	Age 18-34yrs	EMS transport to Level I or Level II TC, or non-TC
Hsia et al (2011)	US	Retrospective cohort	430,081	Patients ≥18yrs with trauma defined by ICD 9 codes 800-904.9, 910-929.9 and 950-959.9	Patients without external cause of injuries; scheduled admissions; admitted for late effects of injury. Patients with ICD-9 codes indicative of drowning; bites and stings; overexertion; poisoning or suffocation; ICD-9 codes for minor injuries; closed hip fractures	Age ≤65yrs	Age 18-64yrs	Admission to Level I or Level II TC, or non-TC

Table 2. Characteristics of included studies (continued)

Study	Country	Study design	Sample size	Population	Exclusion	Exposure	Comparison	Outcome
Lane et al (2003)	US	Retrospective cross-sectional	8980	Patients with ICD-9 code signifying an injury as an external cause of the principal diagnosis and ISS >15	Patients with no E-code; burn as the only injury; late effects of injury; an E-code but no codable injury diagnosis (800-959)	Age ≥65yrs	Age <65yrs	Discharge from Level I or Level II TC, or non-TC
Ma et al (1998)	US	Retrospective cohort	7652	Patients of all ages who met at least one ACSTTC for physiology, anatomic injury severity and mechanism of injury	Patients with incomplete physiological parameters recorded. Patients attending a hospital outside Maryland, invalid entries and those attending military hospitals	Age ≥75yrs	Age <75yrs	EMS transport to Level I or Level II TC, or non-TC
Nakamura et al (2012)	US	Retrospective cohort	46,414 met trauma triage criteria; 8007 had ISS ≥16	Patients with an EMS primary impression recorded as 'injury' or 'trauma' who met ACSTTC and/or had ISS ≥16	Inter-hospital transfers without the initial presentation involving EMS, non-transported patients and deaths on scene	Age ≥61yrs	Age <61yrs	EMS transport to Level I or Level II TC, or Level III to V TC, or non-TC
Scheetz (2004)	US	Retrospective cohort	817	Patients >25yrs sustaining injuries in motor vehicle crashes with ISS ≥16	No exclusions	Age ≥65yrs	Age 25-64yrs	Admission to Level I or Level II TC, or non-TC
Xiang et al (2014)	US	Retrospective cohort	36,395	Patients with ISS ≥16 in the Nationwide Emergency Department Sample	Patients with only late effects of injury (ICD-9 codes 905-909.9) or injuries due to foreign bodies (ICD-9 code 930-939.9)	Age ≥65yrs	Age 18-64yrs	EMS transport to Level I or Level II TC, or Level III TC, or non-TC including inter-hospital transfers
Zimmer-Gembeck et al (1995)	US	Retrospective cohort	2628	Patients with a hospital discharge diagnosis in ICD-9-CM range 800-959; trauma patients meeting triage criteria and ISS ≥16	Patients with only late effects of injury (ICD-9 codes 905-909) or injuries due to foreign bodies (ICD-9 code 930-939)	Age >65yrs	Age ≤65yrs	Admission to Level I TC, or non-TC

ACSTTC = American College of Surgeons Trauma Triage Criteria, AIS = Abbreviated Injury Scale, EMS = emergency medical service, ICD = International Classification of Diseases, ISS = Injury Severity Score, non-TC = non-trauma centre, TC = trauma centre major trauma compared to younger patients, however, there was high statistical heterogeneity (I^2=100%) and therefore the pooled result was deemed to be unreliable and therefore not reported.

The study undertaken by Davis et al (21) compared patients ≥15 years with a non-trauma related emergency admission with trauma patients who were retrospectively defined as meeting a PTTC. This study found that, compared to patients with a non-traumatic emergency admission, patients meeting a PTTC aged 15–54 years were almost five times more likely to be transported to a TC (OR=4.86, 95% CI 3.51–6.74) (Table 3). However, compared to patients with a non-trauma related emergency admission, patients meeting a PTTC aged ≥55 years had only a 36% increased likelihood of TC transport (OR=1.36, 95% CI 1.05–1.74). From the reported data we were able to calculate those trauma patients aged ≥55 years had a 61% reduced likelihood of TC transport (OR=0.39) compared to those aged 15–54 years. However, this was all trauma patients not specifically those with major trauma.

Beaz et al (18) used the meeting of one element of a PTTC and having an ISS >15 to define major trauma patients. Their study found that the mean age of patients was significantly older in those who were not transported to the TC (63.63±16.0 vs. 46.62 ±18.54 p<0.001) (Table 3). No raw patient numbers were available to compare older and younger major trauma patients. The authors were contacted for further information but we received no response.

Retrospective major trauma diagnosis

The eight studies using a retrospective diagnosis of major trauma reported a reduced likelihood of TC transport in older patients compared to their younger counterparts (10,20,24,26,28,32-34). The pooled effect of these studies showed a reduced likelihood of TC transport in older major trauma patients in comparison with younger patients. However, there was high statistical heterogeneity (I^2=99%), therefore, the pooled result was deemed to be unreliable and therefore not reported. As only the unadjusted OR was available for the study undertaken by Cox et al (20), a sensitivity analysis was undertaken excluding this study, however, the results were similar and statistical heterogeneity remained high (I^2=100%).

A sensitivity analysis was undertaken excluding the studies by Hsia et al (26) and Xiang et al (33) as both of these studies included patients who may not have all been primarily transported by EMS. The results of this analysis showed a reduction in the likelihood of EMS TC transport in older patients compared to younger patients with major trauma, however, statistical heterogeneity remained high (I^2=96%).

As the raw patient numbers reported by Garwe et al (24) included patients who were secondary transfers the authors of this study were contacted for further information, however, no response was received. Therefore a sensitivity analysis was undertaken excluding this study. The results of the sensitivity analysis showed a reduced likelihood of TC transport in older patients in comparison with younger patients, however, there was high statistical heterogeneity (I^2=99%).

There were two studies that analysed specific major trauma subpopulations: those with head injuries and those who died in the ED. Flottemesch et al (23) included only patients with severe head trauma, defined as being an abbreviated injury scale (AIS) score of ≥4. The study used the initial ED presentation as a proxy for pre-hospital triage decision, however, it was unclear if all included patients were transported by EMS, and although attempts were made to contact the authors, we were unable to gain further clarification. This study found that compared with patients aged 18–64 years, patients ≥65 years of age had a 53% reduced likelihood of initial treatment at a TC (OR 0.47, 95% CI 0.46–0.48) (Table 3). Holst et al (25) included only trauma patients who died in the ED and found that patients aged ≥65 years had a 30% reduction in the likelihood of TC transport when compared to those aged 18–64 years (OR=0.70, 95% CI 0.60–0.82) (Table 3).

Davis et al (21) compared the odds of TC transport between trauma patients with an ISS ≥16 and those with a non-trauma related emergency admission. This study found that trauma patients aged 15–54 years had more than six times the odds of TC transport (OR=6.53, 95% CI 4.07–10.47) than those with an emergency classified admission (Table 3). However, for those aged ≥55 years the odds were only 1.67 times (95% CI 1.08–2.58) that of emergency classified admissions.

Other included studies

Nakamura et al (12) used both a PTTC and/or ISS ≥16 to define major trauma and found that after the age of 60 years the percentage of patients transported to a non-TC increased. The unadjusted odds for TC transport in patients aged ≥61 years was 0.32 (95% CI 0.32–0.33) compared to those aged <60 years (Table 3). It is important to note that this refers to all EMS transported trauma patients included in the study, not just those defined prospectively or retrospectively as major trauma. The authors were contacted for further information but we received no response.

Publication bias

The odds ratios for EMS TC transport in studies included in the pooled analysis were used to construct a funnel plot to investigate the likelihood of publication bias (Figure 1). In the absence of bias, the plot should resemble a symmetric inverted funnel (15). If a bias exists, the plot will appear asymmetric with the presence of a gap at the right-hand side of the graph (15). Although the funnel plot does not fully resemble a funnel shape it is not asymmetrical as it would be if a bias existed (36).

Table 3. Results from individual studies

Study	Exposure age	Hospital destination	Comparison age	Hospital destination	Measurement	Unadjusted	Adjusted	Adjusted for confounders
Baez et al (2003)	Not defined-reported mean	Not specified	Not defined-reported mean	Not specified	Mean ± SD	Mean age TC=46.62yrs (±18.54) Mean age non-TC=63.63yrs (±16.02) p<0.001	Not stated	Not stated
Brown et al (2019)	≥65yrs	TC=188 Non-TC=232	16-64yrs	TC=578 Non-TC=168	OR for TC transport	Age ≥65yrs OR=0.24 (95% CI 0.18-0.32)	Age 65-74yrs AOR=0.52 (95% CI 0.35-0.78), 75-84yrs AOR=0.48 (95% CI 0.33-0.71), ≥85yrs AOR=0.37 (95% CI 0.24-0.55	Mechanism of injury, pre-hospital GCS, ISS, major injury (AIS ≥3), gender
Chang et al (2008)	≥65yrs (with 50-69yrs, ≥70yrs as subgroups)	TC=1800 Non-TC =1790	<65yrs (with <50yrs the reference for subgroups)	TC=18,882 Non-TC=4093	OR for TC transport	Age ≥65yrs OR=0.22 (95% CI 0.20-0.23)	Age ≥65yrs AOR=0.48 (95% CI 0.30-0.76) Subgroups: 50-69yrs AOR=0.67 (95% CI 0.57-0.77), ≥70yrs AOR=0.45 (95% CI 0.39-0.53)	Year, gender, physiology, injury, or mechanism criteria, transport reasons, EMS provider training level, presence or absence of 18 specific injuries, jurisdictional region
Cox et al (2014)	>55yrs (with 26-35yrs, 36-45yrs, 46-55yrs, 56-65yrs, 66-75yrs, 76-85yrs, ≥86yrs as subgroups)	Not specified	16-55yrs (with 16-25yrs the reference for subgroups)	Not specified	OR for TC transport	Age >55yrs OR=0.43 (95% CI 0.42-0.44)	Age 26-35yrs OR=1.03 (95% CI 0.95-1.12), 36-45yrs AOR=0.90 (95% CI 0.83-0.97), 46-55yrs AOR=0.85 (95% CI 0.78-0.93), 56-65yrs AOR=0.76 (95% CI 0.69-0.83), 66-75yrs AOR=0.68 (95% CI 0.62-0.75), 76-85yrs AOR=0.58 (95% CI 0.54-0.64), ≥86yrs AOR=0.62 (95% CI 0.56-0.68)	Trauma cause, ISS, paramedic type, comorbidities, inter-hospital transfer, transport time, paramedic judgement, injury count, region
Davis et al (2012)	≥55yrs	Not specified	15-54yrs	Not specified	OR for discharge from TC	Age >55yrs OR=0.43 (95% CI 0.42-0.44) Age ≥55yrs OR=0.39 compared to non-trauma patients, patients meeting Pre-hospital Trauma Triage Criteria 15-54yrs OR=4.86 (95% CI 3.51-6.74) and age ≥55yrs OR=1.36 (95% CI 1.05-1.74) compared to non-trauma patients, patients with ISS ≥16, 15-54yrs OR=6.53 (95% CI 4.07-10.47) and age ≥55yrs OR=1.67 (95% CI 1.08-2.58)	Not stated	Not stated

Table 3. Results from individual studies (continued)

Study	Exposure age	Hospital destination	Comparison age	Hospital destination	Measurement	Unadjusted	Adjusted	Adjusted for confounders
Doumouras et al (2012)	≥65yrs	TC=85 Non-TC=215	16-64yrs (with 16-24yrs, 25-40yrs, 41-54yrs, 55-64yrs as subgroups)	TC=329 Non-TC=206	OR for TC destination	Age ≥65yrs OR=0.25 (95% CI 0.18-0.34)	Age 16-24yrs AOR=3.51 (95% CI 2.00-6.17), 25-40yrs AOR=2.29 (95% CI 1.35-3.87), 41-54yrs AOR=2.21 (95% CI 1.38-3.55), 55-64yrs AOR=1.86 (95% CI 0.99-3.51)	Gender, mechanism, GCS, systolic blood pressure, respiratory rate, heart rate, differential distance
Fitzharris et al (2012)	≥70yrs (with 5.0-14.9yrs, 15-29.9yrs, 30-49.9yrs, 50-69.9yrs, ≥70yrs as subgroups)	TC=812 Non-TC=582	<70yrs (with 0-4.9yrs the reference for subgroups)	TC=6104 Non-TC=1846	OR for TC transport	Age ≥70yrs OR=0.42 (95% CI 0.37-0.48), 5.0-14.9yrs OR=0.87 (95% CI 0.66-1.15), 15-29.9yrs OR=1.12 (95% CI 0.89-1.41), 30-49.9yrs OR=0.99 (95% CI 0.79-1.25), 50-69.9yrs OR=0.79 (95% CI 0.63-1.01), ≥70yrs OR=0.41 (95% CI 0.33-0.53)	Age 5.0-14.9yrs AOR=0.74 (95% CI 0.55-0.98), 15-29.9yrs AOR=0.69 (95% CI 0.54-0.90), 30-49.9yrs AOR=0.65 (95% CI 0.50-0.84), 50-69.9yrs AOR=0.56 (95% CI 0.43-0.72), ≥70yrs AOR=0.38 (95% CI 0.29-0.49)	Vital signs, injury criteria, high-risk mechanism, gender, type of incident, treating officer level, time of day, day of week
Flottemesch et al (2016)	≥65yrs (with 45-64yrs, 65-84yrs, ≥85yrs as subgroups)	TC=37,159 Non-TC=44,999	18-64yrs (with 18-44yrs the reference for subgroups)	TC=37,473 Non-TC=21,135	OR for initial treatment at TC	Age ≥65yrs OR=0.47 (95% CI 0.46-0.48)	Patients with head injuries in 2009: age 45-64yrs AOR= 0.76 (95% CI 0.71-0.81), 65-84yrs AOR=0.61 (95% CI 0.56-0.6 5), ≥85yrs AOR=0.53 (95% CI 0.49-0.57) Patients with head injuries in 2012: age 45-64yrs AOR=0.74 (95% CI 0.69-0.80), 65-84yrs AOR=0.59 (95% CI 0.54-0.63), ≥85yrs AOR=0.56 (95% CI 0.51-0.60)	Demographic, location of residence, expected payer, injury, clinical complexity, geography
Garwe et al (2017)	≥55yrs	TC=6086 Non-TC=6737	17-55yrs	TC=11,696 Non-TC=6036	OR for EMS transport to TC	Age ≥55yrs OR=0.47 (95% CI 0.45-0.49)	Age ≥55yrs AOR=0.49 (95% CI 0.47-0.52)	Gender, mechanism, injury period, distance to closest TC, distance to closest Level III, systolic blood pressure, EMS intubation, severe injury AIS ≥3, long bone fracture, pelvic fracture, pre-existing comorbidity
Holst et al (2016)	≥65yrs (with 35-49yrs, 50-64yrs as subgroups)	TC=487 Non-TC=419	18-64yrs (with 18-34yrs the reference for subgroups)	TC=1494 Non-TC=901	OR for EMS transport to TC	Age ≥65yrs OR=0.70 (95% CI 0.60-0.82)	Age 35-49yrs AOR= 0.86 (95% CI 0.69-1.07), 50-64yrs AOR=0.74 (95% CI 0.59-0.92), ≥65yrs AOR=0.78 (95% CI 0.62-1.00)	Gender, median household income, primary payer, weekend arrival, month of arrival, hospital characteristics, mechanism of injury

Table 3. Results from individual studies (continued)

Study	Exposure age	Hospital destination	Comparison age	Hospital destination	Measurement	Unadjusted	Adjusted	Adjusted for confounders
Hsia et al (2011)	≥65yrs (with 26-45yrs, 46-65yrs, 66-85yrs, ≥85yrs as subgroups)	TC=34,155 Non-TC =84,027	18-65yrs (with 18-25yrs the reference for subgroups)	TC=197,120 Non-TC=114,779	OR for admission to TC	Age ≥65yrs OR=0.24 (95% CI 0.23-0.25)	Age >65yrs AOR=0.53 (95% CI 0.45-0.63), 26-45yrs AOR=0.75 (95% CI 0.71-0.80), 46-65yrs AOR=0.57 (95% CI 0.54-0.60), 66-85yrs OR=0.35 (95% CI 0.30-0.41) ≥85yrs AOR=0.30 (95% CI 0.25-0.36)	Gender, insurance, race/ethnicity, income, ISS, type of injury, Elixhauser comorbidities, proximity to TC, availability of TC, metropolitan statistical area
Lane et al (2003)	≥65yrs	TC=1144 Non-TC=1981	<65yrs	TC=2749 Non-TC=3106	OR for receiving	Age ≥65yrs OR=0.65 (95% CI 0.60-0.70)	Not stated	Not stated
Ma et al (1998)	≥55yrs	TC=10,684 Non-TC=33,207	<55yrs (with 0-14yrs, 15-54yrs, 55-74yrs as subgroups)	TC=8096 Non-TC=16,270	OR for EMS transport to TC	Age ≥55yrs OR=0.65 (95% CI 0.62-0.67)	Patients meeting major trauma criteria: age 0-14yrs AOR=1.53 (95% CI 0.87-2.71), 15-54yrs AOR=1.43 (95% CI 0.93-2.20), 55-74yrs AOR=1.23 (95% CI 0.69-2.20) Patients meeting mechanism criteria only: age 0-14yrs AOR=1.71 (95% CI 1.22-2.38), 15-54yrs AOR=1.35 (95% CI 1.03-1.77), 55-74yrs AOR=1.05 (95% CI 0.75-1.48) Patients meeting physiology criteria: age 0-14yrs AOR=2.71 (95% CI 2.43-3.02), 15-54yrs AOR=1.55 (95% CI 1.43-1.68), 55-74yrs AOR=1.07 (95% CI 0.96-1.19)	Not stated
Nakamura et al (2012)	≥61yrs	TC=16,759 Non-TC=59,498	<61yrs	TC=84,880 Non-TC=98,891	EMS transport to TC	Age ≥61yrs OR=0.32 (95% CI 0.32-0.33)	Not stated	Not stated
Scheetz (2004)	≥65yrs	TC=134 Non-TC=88	25-64yrs	TC=467 Non-TC=128	OR for admission to TC	Age ≥65yrs OR=0.42 (95% CI 0.30-0.59)	Not stated	Not stated
Xiang et al (2014)	≥65yrs (with 55-64yrs, 65-74yrs, 75-84yrs, ≥85yrs as subgroups)	TC=7443 Non-TC=7295	18-64yrs	TC=16,129 Non-TC=5523	OR for treatment, admission or death at TC	Age ≥65 OR=0.37 (95% CI 0.35-0.38), 55-64yrs OR=0.61 (95% CI 0.54-0.69), 65-74yrs OR=0.39 (95% CI 0.33-0.47), 75-84yrs OR=0.31 (95% CI 0.25-0.38) ≥85yrs OR=0.23 (95% CI 0.18-0.29)	Patients with ISS ≥16: age 55-64yrs AOR=0.74 (95% CI 0.66-0.83), 65-74yrs AOR=0.63 (95% CI 0.52-0.76), 75-84yrs AOR=0.58 (95% CI 0.47-0.74), ≥85yrs AOR=0.49 (95% CI 0.38-0.63)	Gender, chronic condition, primary expected payer, median household income, patient location, external cause, admission on weekend

Table 3. Results from individual studies (continued)

Study	Exposure age	Hospital destination	Comparison age	Hospital destination	Measurement	Unadjusted	Adjusted	Adjusted for confounders
Zimmer-Gembeck et al (1995)	>65yrs	TC=912 Non-TC=316	≤65yrs	TC=1156 Non-TC=249	OR for admission to TC	Age >65yrs OR=0.62 (95% CI 0.52-0.74)	Age ≥65yrs AOR=0.18 (95% CI not available)	Gender, comorbidities, multisystem injury, AIS for all injury regions

AIS = Abbreviated Injury Scale, AOR = adjusted odds ratio, CI = confidence interval, EMS = emergency medical service, GCS = Glasgow Coma Score, ISS = Injury Severity Score, Non-TC = non-trauma centre, OR = odds ratio, SD = standard deviation, TC = trauma centre

Discussion

Summary of evidence

We identified 17 studies that described the association between age and EMS TC transport, using the definition of major trauma as either patients meeting a PTTC or a retrospective diagnosis. Overall, we found that all studies reported a reduced likelihood of EMS transport to a TC in older patients when compared to younger patients. However, the pooled result of these studies was highly statistically heterogeneous and therefore a meta-analysis could not be performed. To our knowledge, this is the first systematic review undertaken to answer this question. As the results of this study suggest that older patients are unequivocally less likely to be transported to a TC, it is necessary to gain an understanding as to why this under triaging occurs and how this can be addressed.

There were five studies included in this review that used a PTTC to define their major trauma patients. The reasons for older patients who meet a PTTC not being transported by EMS to TCs are likely to be multifaceted. Suggested reasons for this occurring include, but are not limited to, poor adherence to the triage guidelines (37), geographic location (24,38), ambulance diversion, physician or law enforcement choice (37) and feeling of not being welcome at TCs when transporting older adults with suspected major trauma (19). However, the most common reason for selecting transport to specific hospitals was found by Newgard et al to be patient or family choice (37). Furthermore, Newgard et al found that the influence of patient or family choice on the selection of hospitals increases with patient age (37) and this is likely to be due to patients' prior history at local hospitals (19,39). It is also plausible that although an older trauma patient may meet a PTTC, EMS providers consider that active trauma care as futile or 'not worth it' due to age, injury severity, existing comorbidities and likely prognosis and therefore, choose not to transport older patients to the TC (10,19).

It is important to note that the studies that used PTTC alone (without a concurrent retrospective diagnosis), are likely to underestimate the magnitude of the under triaging of older patients and over triaging of patients who will later be found not to have major trauma on retrospective diagnosis. Standard adult triage criteria have been found to be too restrictive in identifying the need for TC care in older patients (40-42). Reasons for this include the ability of older patients to sustain major trauma as a result of low-velocity mechanisms such as falls (12), which are often not recognised as a mechanism of injury on PTTCs (42). Furthermore, after trauma, older patients have the ability to appear deceptively uninjured (43) and often have significant comorbidities, polypharmacy, anticoagulation therapy and physiologic changes that can alter their response to a traumatic insult (12). For example, for the equivalent severity of intracranial injury, the presenting Glasgow Coma Scale score is higher in older patients than their younger counterparts (44). Similarly, vital signs have been found to be different and less predictive of mortality in older trauma victims than younger patients (42,45). Older patients are also more susceptible to occult hypoperfusion, which requires high levels of suspicion to recognise (12). This lack of overt physiological derangement results in older trauma patients not meeting the physiological criteria of the PTTC (42).

The studies that use a retrospective diagnosis of major trauma will have produced a better estimate of the under triaging of older patients with major trauma. However, it is important to

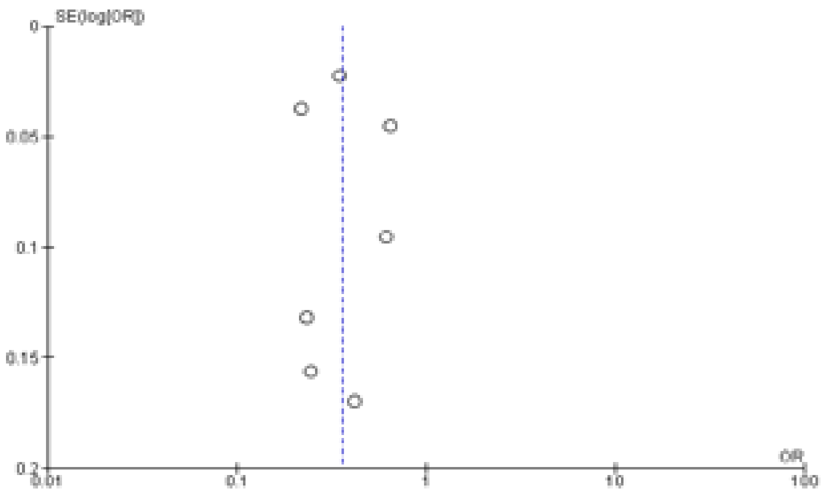

Figure 1. Funnel plot of publication bias using the odds ratio of EMS transport to a trauma centre
x-axis= odds ratio (OR), y-axis= standard error of the log odds ratio (SE log OR)

consider that these diagnoses are based on information that is not necessarily available pre-hospital, such as results from imaging. It is, therefore, important to develop ways in which to identify pre-hospital major trauma in older patients and ensure that these patients receive appropriate care. For example, the adoption of specific PTTC has been shown to significantly improve the detection of older patients requiring this specialised care (40). However, this increase in sensitivity needs to occur without resulting in unnecessary levels of over triaging (reduced specificity). Similarly, further EMS provider training in regard to older patient response to trauma insults may assist in better identification of major trauma in older patients (19).

Limitations

Despite searching for grey literature, a limitation of this study could be the non-identification of unpublished literature. Publication bias is thought to occur with the favouring of positive results for publication (46). Although our funnel plot did not provide evidence of asymmetry, bias cannot be fully excluded (15). Furthermore, a reporting bias may be present as, although we did not have any language restrictions, studies published in a language other than English may have been missed in our search (36). The studies included in the review were from three countries, Australia, Canada and the United States, it is not possible to determine whether the findings could be extrapolated to EMS systems in other countries. It was not possible to report definitions of older and younger age in the composite data as different definitions were used within the PTTC and retrospective major trauma diagnosis groups.

Conclusion

The studies included in this review all showed that older age is associated with a reduced likelihood of EMS TC transport when compared to younger age in major trauma patients. Ensuring that older major trauma patients have access to appropriate hospital care is important. This may be achieved by employing interventions aimed at reducing the rate of under triaging, including specific PTTCs for older adults and focusing on extended EMS training pertaining to the complexities of major trauma in these patients.

Competing interests

Elizabeth Brown, Hideo Tohira, Paul Bailey and Judith Finn are the authors of a study included in this review. Paul Bailey is the Medical Director of St John Western Australia (SJ-WA) and Judith Finn receives partial salary support from SJA-WA. Elizabeth Brown is a SJ-WA paramedic and was a PhD candidate and the recipient of a scholarship funded by a National Health and Medical Research Council Prehospital Emergency Care Centre for Research Excellence grant (1116453). Each author of this paper has completed the ICMJE conflict of interest form.

Acknowledgements

The authors would like to thank Peter Buzzacott for his independent assessment of our study against the eligibility criteria and his independent risk of bias assessment.

References

1. Haagsma JA, Graetz N, Bolliger I, et al. The global burden of injury: Incidence, mortality, disability-adjusted life years and time trends from the global burden of disease study 2013. Inj Prev 2016;22:3-18.
2. Lang J, Dallow N, Lang A, et al. Inclusion of 'minor' trauma cases provides a better estimate of the total burden of injury: Queensland trauma registry provides a unique perspective. Injury 2014;45:1236-41.
3. Kehoe A, Smith JE, Edwards A, Yates D, Lecky F. The changing face of major trauma in the UK. Emerg Med J 2015;32:911-5.
4. Hashmi A, Ibrahim-Zada I, Rhee P, et al. Predictors of mortality in geriatric trauma patients: a systematic review and meta-analysis. J Trauma 2014;76:894-901.
5. Williams T, Finn J, Fatovich D, Jacobs I. Outcomes of different health care contexts for direct transport to a trauma center versus initial secondary center care: a systematic review and meta-analysis. Prehosp Emerg Care 2013;17:442-57.
6. Sasser SM, Hunt RC, Faul M, et al. Guidelines for field triage of injured patients: Recommendations of the national expert panel on field triage, 2011. In: Prehospital control of traumatic external hemorrhage: literature review and evidence analysis of tourniquets and hemostatic dressings. Nova Science Publishers, Inc. 2014. p. 155-86.
7. MacKenzie EJ, Rivara FP, Jurkovich GJ, et al. A national evaluation of the effect of trauma-center care on mortality. N Engl J Med 2006;354:366-78.
8. Haas B, Stukel TA, Gomez D, et al. The mortality benefit of direct trauma center transport in a regional trauma system: a population-based analysis. J Trauma 2012;72:1510-5.
9. Pracht EE, Langland-Orban B, Flint L. Survival advantage for elderly trauma patients treated in a designated trauma center. ibid. 2011;71:69-77.
10. Brown E, Tohira H, Bailey P, et al. Older age is associated with a reduced likelihood of ambulance transport to a trauma centre after major trauma in Perth. Emerg Med Australas (In press).
11. Fitzharris M, Stevenson M, Middleton P, Sinclair G. Adherence with the pre-hospital triage protocol in the transport of injured patients in an urban setting. Injury 2012;43:1368-76.
12. Nakamura Y, Daya M, Bulger EM, et al. Evaluating age in the field triage of injured persons. Ann Emerg Med 2012;60:335-45.
13. Staudenmayer KL, Hsia RY, Mann NC, Spain DA, Newgard CD. Triage of elderly trauma patients: a population-based perspective. J Am Coll Surg 2013;217:569-76.

References (continued)

14. Moher D LA, Tetzlaff J, Altman DG, et al. The PRISMA statement. Preferred reporting items for systematic reviews and meta-analyses. BMJ 2009;6:1-6.
15. Higgins JP. Cochrane handbook for systematic reviews of interventions Version 5.1.0: The Cochrane Collaboration; 2011. [Updated September 2018]. Available at: https://handbook.cochrane.org [Accessed 10 December 2018].
16. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ 2003;327:557-60.
17. Collaboration Community. RevMan 5 [Updated February 2019]. Available at: https://community.cochrane.org/help/tools-and-software/revman-5 [Accessed 20 February 2019].
18. Baez AA, Lane PL, Sorondo B. System compliance with out-of-hospital trauma triage criteria. J Trauma 2003;54:344-51.
19. Chang DC, Bass RR, Cornwell EE, Mackenzie EJ. Undertriage of elderly trauma patients to state-designated trauma centers. Arch Surg 2008;143:776-81.
20. Cox S, Morrison C, Cameron P, Smith K. Advancing age and trauma: triage destination compliance and mortality in Victoria, Australia. Injury 2014;45:1312-9.
21. Davis JS, Allan BJ, Sobowale O, et al. Evaluation of a new elderly trauma triage algorithm. South Med J 2012;105:447-51.
22. Doumouras AG, Haas B, Gomez D, et al. The impact of distance on triage to trauma center care in an urban trauma system. Prehosp Emerg Care 2012;16:456-62.
23. Flottemesch TJ, Raetzman S, Heslin KC, et al. Age-related disparities in trauma center access for severe head injuries following the release of the updated field triage guidelines. Acad Emerg Med 2017;24:447-57.
24. Garwe T, Stewart K, Stoner J, et al. Out-of-hospital and inter-hospital under-triage to designated tertiary trauma centers among injured older adults: a 10-year statewide geospatial-adjusted analysis. Prehosp Emerg Care 2017;21:734-43.
25. Holst JA, Perman SM, Capp R, Haukoos JS, Ginde AA. Undertriage of trauma-related deaths in U.S. emergency departments. West J Emerg Med 2016;17:315-23.
26. Hsia RY, Wang E, Saynina O, et al. Factors associated with trauma center use for elderly patients with trauma: a statewide analysis, 1999-2008. Arch Surg 2011;146:585-92.
27. Kodadek LM, Selvarajah S, Velopulos CG, Haut ER, Haider AH. Undertriage of older trauma patients: is this a national phenomenon? J Surg Res 2015;199:220-9.
28. Lane P, Sorondo B,Kelly JJ. Geriatric trauma patients. Are they receiving trauma center care? Acad Emerg Med 2003;10:244-50.
29. Ma MH, MacKenzie EJ, Alcorta R, Kelen GD. Compliance with prehospital triage protocols for major trauma patients. J Trauma 1999;46:168-75.
30. Ryb GE, Dischinger PC. Disparities in trauma center access of older injured motor vehicular crash occupants. ibid. 2011;71:742-7.
31. Scheetz LJ. Effectiveness of prehospital trauma triage guidelines for the identification of major trauma in elderly motor vehicle crash victims. J Emerg Nurs 2003;29:109-15.
32. Scheetz LJ. Trauma center versus non-trauma center admissions in adult trauma victims by age and gender. Prehosp Emerg Care 2004;8:268-72.
33. Xiang H, Wheeler KK, Groner JI, Shi J, Haley KJ. Undertriage of major trauma patients in the US emergency departments. Am J Emerg Med 2014;32:997-1004.
34. Zimmer-Gembeck MJ, Southard PA, Hedges JR, et al. Triage in an established trauma system. J Trauma 1995;39:922-8.
35. Cox S, Currell A, Harriss L, et al. Evaluation of the Victorian state adult pre-hospital trauma triage criteria. Injury 2012;43:573-81.
36. Sedgwick P. Meta-analyses: How to read a funnel plot. BMJ 2013;346:1-2.
37. Newgard CD, Mann NC, Hsia RY, et al. Patient choice in the selection of hospitals by 9-1-1 emergency medical services providers in trauma systems. Acad Emerg Med 2013;20:911-9.
38. Newgard CD, Fu R, Bulger E, et al. Evaluation of rural vs urban trauma patients served by 9-1-1 emergency medical services. JAMA Surg 2017;152:11-8.
39. Beck B, Cameron P, Lowthian J, et al. Major trauma in older persons. BJS Open 2018;2:310-8.
40. Ichwan B, Darbha S, Shah MN, et al. Geriatric-specific triage criteria are more sensitive than standard adult criteria in identifying need for trauma center care in injured older adults. Ann Emerg Med 2015;65:92-100.
41. Newgard CD, Fu R, Zive D, et al. Prospective validation of the national field triage guidelines for identifying seriously injured persons. J Am Coll Surg 2016;222:146-58.
42. Nishijima DK, Gaona SD, Waechter T, et al. Out-of-hospital triage of older adults with head injury: Adding “anticoagulation or antiplatelet medication use” as a criterion. Ann Emerg Med 2017;70:127-38.
43. Fatovich DM, Burrell M, Jacobs IG. Major trauma deaths at Perth secondary hospitals. Emerg Med Australas 2011;23:754-60.
44. Kehoe A, Smith JE, Bouamra O, et al. Older patients with traumatic brain injury present with a higher GCS score than younger patients for a given severity of injury. Emerg Med J 2016;33:381-5.
45. Lehmann R, Beekley A, Casey L, Salim A, Martin M. The impact of advanced age on trauma triage decisions and outcomes: a state wide analysis. Am J Surg 2009;197:571-5.
46. Egger M. Under the meta-scope: possibilities and limits of meta-analyses. Schweiz Med Wochenschr 1998;128:1893-901.