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Review

Risk factors that predict mortality in patients with blunt chest wall trauma: A systematic review and meta-analysis

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SUMMARY

Background: The risk factors for mortality following blunt chest wall trauma have neither been well established or summarised.
Objective: To summarise the risk factors for mortality in blunt chest wall trauma patients based on available evidence in the literature.
Data sources: A systematic review of English and non-English articles using MEDLINE, EMBASE and the Cochrane Library from their introduction until May 2010. Additional studies were identified by hand-searching bibliographies and contacting relevant clinical experts. Grey literature was sought by searching abstracts from all Emergency Medicine conferences. Broad search terms and inclusion criteria were used to reduce the number of missed studies.
Study selection: A two step study selection process was used. All published and unpublished observational studies were included if they investigated estimates of association between a risk factor and mortality for blunt chest wall trauma patients.
Data extraction: A two step data extraction process using pre-defined data fields, including study quality indicators.
Study appraisal and synthesis: Each study was appraised using a previously designed quality assessment tool and the STROBE checklist. Where sufficient data were available, odds ratios with 95% confidence intervals were calculated using Mantel–Haenszel method for the risk factors investigated. The I^2 statistic was calculated for combined studies in order to assess heterogeneity.
Results: Age, number of rib fractures, presence of pre-existing disease and pneumonia were found to be related to mortality in 29 identified studies. Combined odds ratio of 1.98 (1.86–2.11, 95% CI), 2.02 (1.89–2.15, 95% CI), 2.43 (1.03–5.72, 95% CI) and 5.24 (3.51–7.82) for mortality were calculated for blunt chest wall trauma patients aged 65 years or more, with three or more rib fractures, pre-existing conditions and pneumonia respectively.
Conclusions: The risk factors for mortality in patients sustaining blunt chest wall trauma were a patient age of 65 years or more, three or more rib fractures and the presence of pre-existing disease especially cardiopulmonary disease. The development of pneumonia post injury was also a significant risk factor for mortality. As a result of the variable quality in the studies, the results of the selected studies should be interpreted with caution.

Contents

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Introduction

Blunt chest wall trauma does not involve any opening of the chest wall and can vary in severity from minor bruising or an isolated rib fracture to severe crush injuries on both sides of the thorax leading to potentially fatal respiratory compromise.[52] Blunt chest wall trauma accounts for over 10% of all trauma patients presenting to emergency departments worldwide.[53] Research has highlighted significant morbidity and mortality for the blunt chest wall trauma patient, with reported mortality ranging from 4 to 20%.[38,53] The patient with severe thoracic injuries will be managed in the Emergency Department by trauma and various surgical teams and intervention is dictated by the resuscitation protocol of the department.[8] Disposition of chest injury patients from the Emergency Department is therefore straightforward when the patient requires immediate surgery or supportive mechanical ventilation.[8] When the injury is not as severe, or associated injuries are not present, deciding which blunt chest wall trauma patients require a higher level of clinical input can be difficult. Clinical symptoms are not considered an accurate predictor of outcome following non-life threatening blunt chest wall trauma.[15]

Pape et al. developed a scoring system for guiding initial clinical decision making in the blunt chest trauma patient with multiple associated injuries however there are currently no evidence-based guidelines to guide patient management in the blunt chest wall trauma population with no associated injuries.[35] Ahmad et al. suggested that a scoring system needs to be designed to evaluate the degree of injury following blunt chest trauma.[1] Methods are required to assist identification of the patient who presents with non-immediate life threatening blunt chest wall trauma, but will develop complications within the following 24–72 h.[1,15] Evidence suggests that these patients can deteriorate up to a week after initial presentation to the Emergency Department[28,41] and elderly blunt chest wall trauma patients are particularly at risk of delayed deterioration.[3,42] The appropriate management of the blunt chest wall trauma patient with no immediate life threatening injuries has been an area of interest in previous research which has highlighted the difficulty in identifying the high risk patient in this population.[30,31,40] Blecher et al. described a group of chest trauma patients who were considered suitable for ward management by the Emergency Department, of which 10% went on to require Intensive Care Unit admission with associated longer lengths of stay and higher rehabilitation requirements.[8]

Risk factors for mortality in the blunt chest wall trauma patient have been investigated previously in the literature and various outcome measures are used including mortality, morbidity and different aspects of resource consumption. When provided, definitions for these outcome measures vary in each study, leading to questionable validity and difficulty in comparison of studies. Given the inconsistent definitions for these outcomes, this study focussed specifically on the risk factors for mortality in blunt chest wall trauma patients as this is the most consistently measured and reported outcome measure. The aim of this review was to summarise the risk factors for mortality in the blunt chest wall trauma patient in order to assist in the identification of the high risk patient and facilitate decisions regarding the required appropriate level of care. For the purpose of this study, we defined blunt chest wall trauma as blunt chest injury resulting in chest wall contusion or rib fractures, with or without non-immediate life-threatening lung injury.

Materials and methods

Search strategy

All methods used in this review followed the CRD[13] PRISMA,[34] and MOOSE[47] guidelines. A broad search strategy was used in order to include all relevant studies. The search filter was used for Medline and Embase Databases and the Cochrane Library from their introduction until June 2010. The search term combinations were Medical Subject Heading (MeSH) terms, text words and word variants for chest trauma. These were combined with relevant terms for aetiological factors. The search terms are illustrated in Table 1.

The references of all primary studies and review articles were hand-searched in order to identify studies missed in the electronic search. In addition, the Annals of Emergency Medicine, Emergency Medicine Journal, Injury and the Journal of Trauma were hand-searched from their introduction until the end of May 2010 for relevant studies. The authors of the studies selected for inclusion in this review were contacted in order to provide expert opinion on further studies for inclusion and a deadline for response was set at three months. All available worldwide Emergency Medicine Conference abstracts were also searched. In addition, OpenSIGLE (System for Information on Grey Literature in Europe) which provides access to grey literature produced in Europe from 1980 until 2005, the National Technical Information Service and Health Management Information Consortium databases which include unpublished papers were all searched to identify grey literature.

The searches were international and no search limitations were imposed. Table 2 highlights the inclusion and exclusion criteria used for study selection. Studies in which the focus was investigating patients with only severe intra-thoracic injuries

Table 1
Keyword combinations used in the literature search.

Chest trauma	AND	Prognos*
Thora* trauma		Predictor
Rib fractures		Caus*
Thora* injury		Risk factors
Chest injury		Risk
Wounds, non-penetrating		Outcome

The asterik indicates where the truncated version of the word was used.

Table 2
Inclusion and exclusion criteria for study selection.

	Inclusion	Exclusion
Population	Studies investigating patients presenting to the ED with blunt chest wall trauma (blunt chest injury resulting in chest wall contusion or rib fractures, with or without underlying lung injury)	Studies investigating: (a) Patients with penetrating trauma only (b) Patients with multi-trauma only and no reference to chest trauma (c) Patients with intra-thoracic injuries only and no chest wall trauma. (d) Scoring systems or prognostic tools
Outcomes	Studies investigating mortality in patients with blunt chest wall trauma	Studies investigating management or treatment strategies only
Comparators	Studies allowing estimates of association between risk factor and outcome for blunt chest wall trauma	Studies that fail to provide comparative data on risk factors and outcome.
Study design	All observational studies, published and unpublished	Descriptive studies with no comparative data such as a narrative review or case studies

such as bronchial cardiac, oesophageal, aortic or diaphragmatic rupture were excluded.

Study selection

A two-step process for selecting the studies was used to reduce selection bias. Two researchers analysed each title and abstract independently and then met to discuss any discrepancies. No restrictions were applied on the year of publication, risk factors or outcomes investigated and age of the subjects. The selected studies were obtained and the full paper analysed by the reviewers using the same two-step process.

Data collection

A previously piloted data extraction form was used to record information about study design, population, sample size, risk factors, outcome measures and results. Study authors were contacted for any missed data. Studies were grouped according to risk factors investigated.

Quality assessment

The studies methodological quality was evaluated using a previously designed criteria list adapted from Duckitt and Harrington,[16] outlined in Table 3. This tool was used as it was designed for quality assessment of observational studies and was used to assess the same components of methodological quality in their systematic review that we set out to investigate. A total validity score was not calculated in this study to summarise quality assessment as guidelines have stated that such scores are unreliable and not recommended.[15,34,47]

Each component of the quality assessment was allocated a score between 0 and 2 following the descriptions as outlined in Table 3, using the two-step process described for study selection. Studies were not excluded on the basis of quality, but any existing quality issues were highlighted in the discussion. The STROBE checklist was used to further assess the studies quality and issues highlighted were included in the discussion.[51]

Statistical analysis

Where sufficient data were available, the odds ratios with 95% confidence intervals were calculated for the risk factors investigated. Statistical analysis was completed using the RevMan software.[39] The I^2 statistic was calculated for combined studies in order to assess heterogeneity and true effect size.[23] Combined odds ratios were calculated using Mantel–Haenszel method with a fixed effect model for each outcome measure. Meta-analysis was only completed for the risk factors that had comparable data.[27]

Table 3
Quality assessment of non-randomised studies.

Patient selection
Selected cohort was representative of the general blunt chest trauma population (1)
Cohort was a selected group or the selection was not described (0)
Comparability of groups
No differences between the groups was explicitly reported (especially in terms of age, number of rib fractures, pre-existing disease) unless it was one of the variables under investigation, or such differences were adjusted for (2)
Differences in groups were not recorded (1)
Groups differed or no comparable group used (0)
Outcomes
Referenced definition of chest trauma (2)
Explicit definition that included explanation of thoracic structures injured or type of injury incurred (1)
Chest trauma not defined (0)
Group size
>100 participants in each group (2)
<100 participants in each group (1)
Cohort design
Prospective cohort design (2)
Retrospective design/use of trauma registry or database (1)

Adapted from Duckitt and Harrington.[16]
NB. Numbers in brackets are the individual quality scores for each methodology sub-section.

Results

A total of 4326 citations were identified from the electronic searches and 25 citations through other sources. Following screening of the titles and abstracts using the two-step process, a total of 73 full-text citations was retrieved for detailed evaluation. No further citations were identified through the searches of grey literature. The experts in the field who responded suggested studies for inclusion that had been identified in the original search. Two non-English language studies were identified and translated. Following critical appraisal of the 73 studies identified in the literature search, a total of 44 studies were excluded, based on the defined exclusion criteria. Fig. 1 indicates the study selection process.

The main results for each risk factor for mortality are illustrated in Table 4.

Using the STROBE checklist[51] and quality assessment process[16] the quality of the studies selected for this review was considered variable, with only a small number of studies scoring maximum marks on each component. All but three of the studies used a retrospective study design, 11 studies used a sample that did not represent the entire blunt chest trauma population and 12 studies had sample size smaller than 100 in each group. The results of the quality assessment process are illustrated in Table 5.

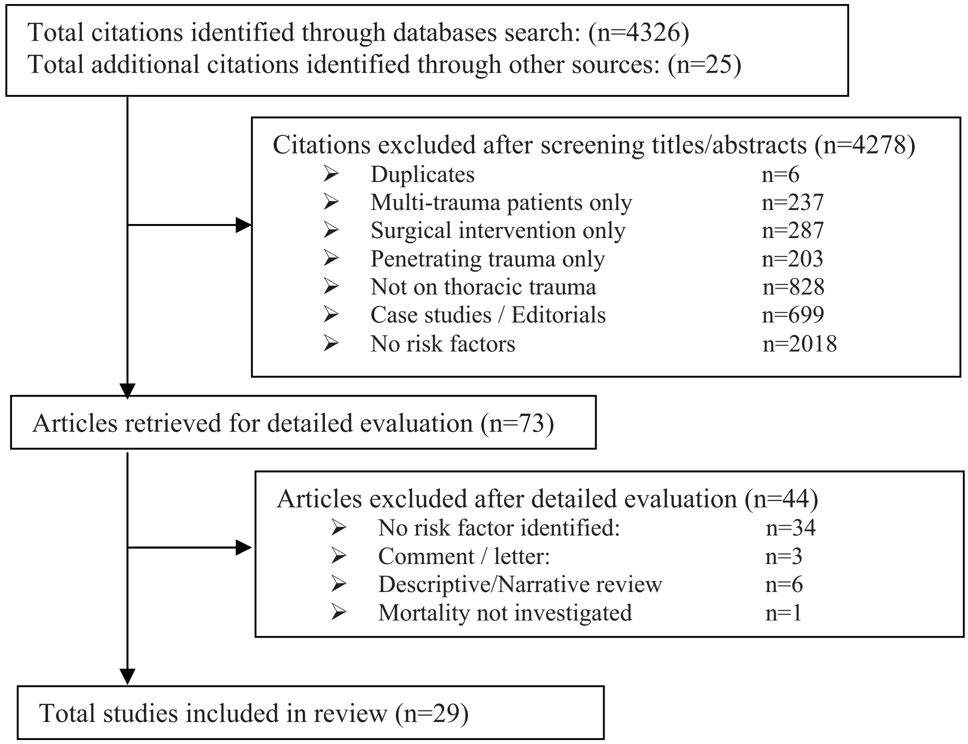

Fig. 1. Flow diagram of study selection process.

Age

Eight studies reported a statistically significant increase in mortality rate in blunt chest wall trauma patients aged 65 years or more,[9,11,12,30,32,41,42,46] with three studies reporting a statistically significant increase in mortality rate in patients aged 60 years or more.[26,33,44] Kulshrestha et al. reported a four percent increase in odds of mortality for each one year increase in age.[29] Advanced age was reported to be a risk factor for mortality in flail chest patients in three studies[2,10,36] but was not associated with mortality in two other studies investigating outcomes in flail chest patients.[4,5] Meta-analysis was only completed for the studies where the study population, dependent and independent variables were comparable. The studies investigating the age of 65 or more years as a risk factor for mortality were combined for analysis and are illustrated in Fig. 2.

Fig. 2 indicates a combined odds ratio for mortality of 1.98 (1.86–2.11, 95% CI) in blunt chest trauma patients aged 65 or more years. An I^2 statistic of 0% indicates a low level of heterogeneity between the studies for this risk factor and outcome measure. The result of the test for overall effect, $Z = 21.67$ ($p < 0.00001$) suggests that the odds of mortality is significantly greater in blunt chest wall trauma patients aged 65 or more.

Number of rib fractures

Seven studies concluded that patients sustaining three or more rib fractures were at significantly increased risk of mortality.[9,11,30,32,33,36,41] Four studies reported a correlation between an increasing number of rib fractures with increased patient mortality.[9,12,18,46] In contrast, four studies reported no differences in mortality rates for any given number of rib fractures.[17,24,25,49] Fig. 3 illustrates the results of the combined studies for odds of mortality and 95% confidence intervals in patients with three or more rib fractures.

Fig. 3 indicates a combined odds ratio for mortality in patients with three or more rib fractures of 2.02 (1.89–2.15, 95% CI). The I^2 statistic of 39% for this meta-analysis however indicates a moderate level of heterogeneity between the included studies. The Z result of 21.83 ($p < 0.00001$) suggests that the overall effect is significant and therefore the odds of death in patients with three or more rib fractures is significantly

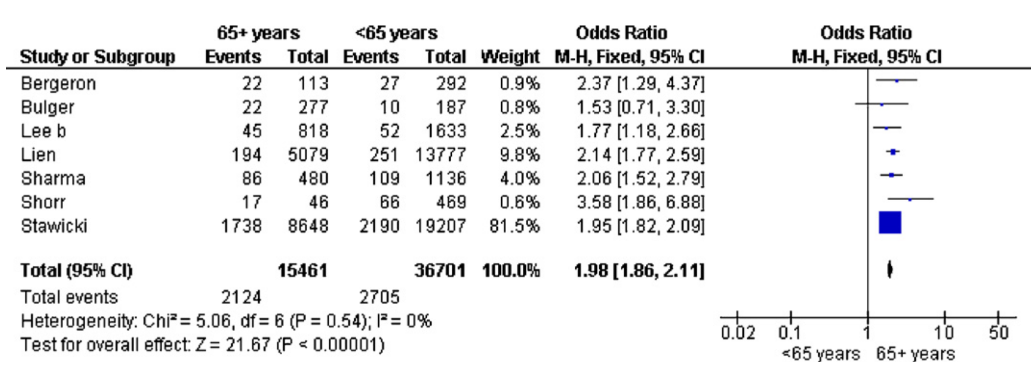

Fig. 2. Forest plot illustrating the odds of mortality with 95% confidence intervals in blunt chest trauma patients aged 65 or more years.

Table 4
Table of extracted data illustrating the studies main results for mortality.

Study	Population	*N*	Risk	Results
Albaugh et al.[1]	Flail chest patients	58	Age	Likelihood of death increases by 132% for each decade of life
Athanassiadi et al.[4]	Flail chest patients	150	Age	Age had no effect on mortality in flail chest patients
Athanassiadi et al.[5]	Flail chest patients	250	Age	Age had no effect on mortality in flail chest patients
Bergeron et al.[9]	Rib fracture patients	405	Age	Adjusted OR of death for RF patients aged 65+ years: 5.03 (1.8–13.9)
Borman et al.[10]	Flail chest patients	262	Age	OR of death in flail chest patients aged 45–64 years: 1.7 (0.8–3.7). OR death in flail chest patients aged 65 years+: 2.1 (1.0–4.6)
Brasel et al.[11]	Rib fracture patients	17,308	Age	Adjusted OR of death for RF patients aged 65–74 years: 2.7 (1.1–7.1)
Bulger et al.[12]	Rib fracture patients	464	Age	RF patients aged 65+ years had higher mortality ($p < 0.001$)
Harrington et al.[22]	Rib fracture patients, aged 50 years+	1621	Age	OR death in RF patients aged 50years+: 1148.5 (184.9–7132.6)
Holcomb et al.[25]	Rib fracture patients, (excl: head, abdominal injuries and <15 years age)	171	Age	No differences in mortality in RF patients aged <45 years or 45 years+
Inci et al.[26]	Blunt chest trauma patients	101	Age	RF patients aged 60+ years had higher mortality ($p < 0.001$)
Kulshrestha et al.[29]	Blunt chest trauma patients	1359	Age	OR death with each 1 year increase in age: 1.04 (1.02–1.05)
Lee et al.[30]	Rib fracture patients	105,493	Age	3+ F patients aged 65+ ears had higher mortality ($p < 0.001$)
Lien et al.[32]	Rib fracture patients aged 18 years+ post MVA	18,856	Age	Adjusted OR death in RF patients aged 65–74years: 2.21 (1.63–2.99)
Liman et al.[33]	Blunt chest trauma patients	1490	Age	RF patients aged 60+ years had higher mortality ($p < 0.001$)
Perna et al.[36]	Blunt chest trauma patients	500	Age	Blunt chest trauma patients aged 55+ years had higher rate of mortality ($p < 0.05$)
Peterson et al.[37]	Blunt chest trauma patients	2073	Age	Blunt chest trauma patients aged 60+ years had higher mortality
Sharma et al.[41]	Rib fracture patients	808	Age	RF patients aged 65+ years had higher mortality ($p < 0.05$)
Shorr et al.[42]	Rib fracture patients	92	Age	RF patients aged 65+ years had higher mortality ($p < 0.001$)
Sirmali et al.[44]	Rib fracture patients	1417	Age	RF patients aged 60+ years had higher mortality
Stawicki et al.[46]	Rib fracture patients aged 18 years+	27,855	Age	RF patients aged 65+ years had higher mortality ($p < 0.001$)
Svennevig et al.[48]	Blunt chest trauma (excl head injury or <12 years)	262	Age	RF patients aged 70+ years had higher mortality ($p < 0.05$)
Testerman et al.[49]	Rib fracture patients, (excl: head, abdominal injuries and <15 years age)	307	Age	No differences in mortality in RF patients aged <45 years or 45 years+
Barnea et al.[7]	Isolated rib fracture patients aged 65years+	77	Number of RF	Correlation between increasing number of RF and increased mortality ($p = 0.006$)
Bergeron et al.[9]	Rib fracture patients	405	Number of RF	Adjusted OR of death for 3+ F patients: 3.13 (1.3–.6)
Brasel et al.[11]	Rib fracture patients	17,308	Number of RF	Adjusted OR of death for 3+ RF patients: 1.8 (1.1–3.0)
Bulger et al.[12]	Rib fracture patients	464	Number of RF	OR death with each additional RF: 1.19
Flagel et al.[18]	Rib fracture patients	64,750	Number of RF	Mortality increases with each successive RF ($p < 0.02$)
Hoff et al.[24]	Isolated pulmonary contusion patients	94	Number of RF	No correlation between number of RFs and mortality
Kulshrestha et al.[29]	Blunt chest trauma patients	1359	Number of RF	OR death for 5+ RF patients: 2.43 (1.31–4.51)
Lee et al.[31]	Rib fracture patients	3282	Number of RF	3+ RF patients had higher mortality than 0–2 RF patients
Lee et al.[30]	Rib fracture patients	105,493	Number of RF	3+ RF patients had higher mortality ($p < 0.001$)
Lien et al.[32]	Rib fracture patients aged 18 years+ post MVA	18,856	Number of RF	Adjusted OR death for 3+ RF patients: 2.44 (0.93–6.41)
Liman et al.[33]	Blunt chest trauma patients	1490	Number of RF	3+ RF patients had higher mortality ($p < 0.001$)
Perna et al.[36]	Blunt chest trauma patients	500	Number of RF	3+ RF patients had higher mortality ($p < 0.05$)
Sharma et al.[41]	Rib fracture patients	808	Number of RF	3+ RF patients had higher mortality ($p < 0.05$)
Sirmali et al.[44]	Rib fracture patients	1417	Number of RF	6+ RF patients had higher mortality
Stawicki et al.[46]	Rib fracture patients aged 18 years+	27,855	Number of RF	Correlation between increasing number of RF and increased mortality
Svennevig et al.[48]	Blunt chest trauma (excl head injury or <12 years)	262	Number of RF	4+ RF patients had higher mortality ($p < 0.05$)

Alexander et al.[3]	Isolated rib fracture patients aged 65 years+	62	PEC	RF patients with cardiopulmonary disease had higher mortality ($p < 0.05$)
Barnea et al.[7]	Isolated rib fracture aged 65years+	77	PEC	RF patients with congestive heart failure had higher mortality ($p < 0.001$)
Bergeron et al.[9]	Rib fracture patients	405	PEC	Adjusted OR for mortality in RF patients with PEC: 2.98 (1.1–8.3)
Brasel et al.[11]	Rib fracture patients	17,308	PEC	Adjusted OR for mortality in RF patients with congestive heart failure: 2.62 (1.93–3.55)
Elmistekawy and Hammad[17]	Isolated rib fracture patients aged 65 years+	39	PEC	RF patients with chronic lung disease had higher mortality ($p = 0.006$)
Harrington et al.[22]	Rib fracture patients aged 50 years+	1621	PEC	OR mortality in RF patients aged 50years+ with congestive heart failure: 5.7 (1.3–25.0 CI 95%)
Stawicki et al.[46]	Rib fracture patients aged 18 years+	27,855	PEC	Effect of PEC on patient mortality inversely related to number of RF
Bergeron et al.[9]	Rib fracture patients	405	Pneumonia	RF patients with pneumonia had OR for mortality: 3.80 (1.5–9.7)
Brasel et al.[11]	Rib fracture patients	17,308	Pneumonia	RF patients with pneumonia had OR for mortality: 3.5 (2.2–5.7)
Elmistekawy and Hammad[17]	Isolated rib fracture patients aged 60 years+	39	Pneumonia	RF patients with pneumonia had higher rate of mortality ($p = 0.015$)
Harrington et al.[22]	Rib fracture patients aged 50 years+	1621	Pneumonia	RF patients aged 50years+ with pneumonia have a significantly higher rate of mortality ($p < 0.001$)
Svennevig et al.[48]	Blunt chest trauma (excl head injury or <12 years)	262	Pneumonia	RF patients with pneumonia had higher rate of mortality ($p < 0.05$)
Bakhos et al.[6]	Rib fracture patients aged 65 years+	38	Vital capacity	No correlation between vital capacity and mortality

NB. All reported confidence intervals were 95%. All *p*-values given where results were significant. RF, rib fractures; PEC, pre-existing conditions; OR, odds ratios; excl, exclusion; MVA, motor vehicle accident.

Table 5
Quality assessment of included studies (points scored: see protocol Table 3).

Included study	Selection	Comparability	Outcome	Size	Cohort design
Albaugh et al.[2]	0	2	1	1	1
Alexander et al.[3]	0	1	1	1	1
Athanassiadi et al.	0	2	1	1	1
Athanassiadi et al.[5]	0	2	1	1	1
Bakhos et al.[6]	0	0	1	1	1
Barnea et al.[7]	0	1	2	1	1
Bergeron et al.[9]	1	2	2	2	2
Borman et al.[10]	0	1	2	2	1
Brasel et al.[11]	1	2	2	2	1
Bulger et al.[12]	1	2	2	2	1
Elmistekawy and Hammad[17]	0	1	1	1	1
Flagel et al.[18]	1	2	2	2	1
Harrington et al.[22]	0	1	1	2	1
Hoff et al.[24]	0	0	2	1	1
Holcomb et al.[25]	1	2	2	1	1
Inci et al.[26]	1	1	1	2	1
Kulshrestha et al.[29]	1	2	2	2	2
Lee et al.[39]	1	2	2	2	1
Lee et al.[30]	1	2	2	2	1
Lien et al.[32]	0	2	2	2	1
Liman et al.[33]	1	1	1	2	1
Perna et al.[36]	1	2	1	2	2
Peterson et al.[37]	1	1	2	1	1
Sharma et al.[41]	1	2	1	2	1
Shorr et al.[42]	1	1	1	1	1
Sirmali et al.[44]	1	2	1	2	1
Stawicki et al.[46]	1	2	2	2	1
Svennevig et al.[48]	1	1	1	2	1
Testerman et al.[49]	1	2	1	1	1

higher when compared with patients with less than three rib fractures.

Pre-existing conditions

Bergeron et al. reported an adjusted odds ratio of 2.98 (1.1–8.3 95% CI) for mortality in blunt chest trauma patients with a pre-existing condition.[9] Similarly, Brasel et al. reported an adjusted odds ratio of 2.62 (1.93–3.55, 95% CI) for mortality in blunt chest trauma patients with congestive heart failure.[11] Harrington et al. reported an odds ratio of 5.7 (1.3–25.0 CI 95%) for mortality in blunt chest trauma patients aged 50 years or more with congestive heart failure.[22] These studies were not included in the meta-analysis as they investigated blunt chest trauma patients with associated injuries which in comparison to the studies included in the meta-analysis looked at blunt chest wall trauma with no associated injuries. Meta-analysis of the studies investigating pre-existing conditions as a risk factor for mortality was performed and the results are illustrated in Fig. 4.

Fig. 4 highlights a combined odds ratio of 2.43 (1.03–5.72, 95% CI) for mortality. Heterogeneity between the three studies was reported to be low, with an I^2 statistic of 0% however in a meta-analysis with only three studies, this result should be interpreted with caution. The calculated Z statistic of 2.03 ($p = 0.04$) for overall effect size indicates that blunt chest wall trauma patients with pre-existing conditions are at significantly increased risk of death compared with blunt chest wall trauma patients with no pre-existing conditions.

On-set of pneumonia

Bergeron et al. reported that blunt chest wall trauma patients who developed pneumonia had nearly four times the odds of mortality when compared with patients without pneumonia. (OR: 3.80; 95% CI, 1.5–9.7).[9] Brasel et al. reported an odds ratio of 3.5 (2.2–5.7, 95% CI) for mortality in blunt chest wall trauma patients

Study or Subgroup	3+ RFs Events	3+ RFs Total	<3 RFs Events	<3 RFs Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Flagel	2222	19969	1494	25397	86.4%	2.00 [1.87, 2.14]
Lee b	97	2477	1837	103016	6.1%	2.24 [1.82, 2.76]
Lien	43	3018	15	2691	1.2%	2.58 [1.43, 4.65]
Liman	12	214	1	259	0.1%	15.33 [1.98, 118.85]
Sharma	174	1208	94	1075	6.3%	1.76 [1.35, 2.29]
Total (95% CI)		**26886**		**132438**	**100.0%**	**2.02 [1.89, 2.15]**
Total events	2548		3441			

Heterogeneity: Chi² = 6.53, df = 4 (P = 0.16); I² = 39%
Test for overall effect: Z = 21.83 (P < 0.00001)

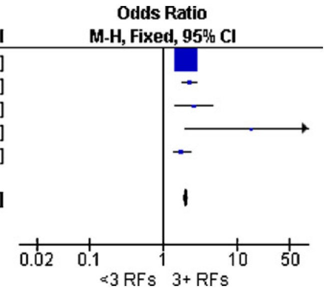

Fig. 3. Forest plot illustrating the odds of mortality with 95% confidence intervals for patients with three or more rib fractures.

Study or Subgroup	PEC Events	PEC Total	No PEC Events	No PEC Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Alexander	3	31	0	31	6.6%	7.74 [0.38, 156.36]
Barnea	8	49	6	60	67.0%	1.76 [0.57, 5.46]
Elmistekawy	4	12	5	33	26.4%	2.80 [0.61, 12.95]
Total (95% CI)		**92**		**124**	**100.0%**	**2.43 [1.03, 5.72]**
Total events	15		11			

Heterogeneity: Chi² = 0.92, df = 2 (P = 0.63); I² = 0%
Test for overall effect: Z = 2.03 (P = 0.04)

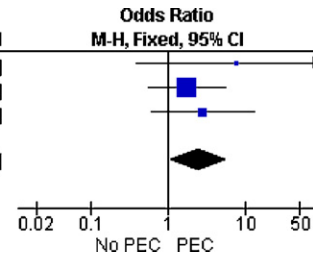

Fig. 4. Forest plot illustrating the odds of mortality with 95% confidence intervals for blunt chest trauma patients with pre-existing conditions.

with no associated injuries who develop pneumonia but pneumonia was not associated with increased mortality in the blunt chest wall trauma patient with associated injuries.[11] Three other studies reported a statistically significantly higher mortality rate in blunt chest wall trauma patients who develop pneumonia.[17,22,48] Meta-analysis for this risk factor is illustrated in Fig. 5.

Fig. 5 highlights a combined odds ratio of 5.24 (3.51–7.82, 95% CI) for mortality in blunt chest wall trauma patients who develop pneumonia. Heterogeneity between the three studies was reported to be low, with an I^2 statistic of 0% however in a meta-analysis with only four studies, this result should be interpreted with caution. The calculated Z statistic of 8.09 ($p < 0.00001$) for overall effect size indicates that blunt chest wall trauma patients who develop pneumonia are at significantly increased risk of death compared with blunt chest wall trauma patients with no pneumonia.

Vital capacity

Vital capacity was not reported to be a risk factor for mortality in the blunt chest wall trauma patient[6] and no further studies were identified which investigated vital capacity.

Discussion

This systematic review was conducted in order to summarise the risk factors for mortality in blunt chest wall trauma patients who can normally be safely discharged from the emergency department, but will develop later complications. Klein et al. stated that controversy remains regarding methods to identify the mild to moderate blunt chest wall trauma group who develop late complications.[28] Studies investigating only severe blunt chest trauma patients, such as intra-thoracic injuries were excluded in order to minimise confounding of this study's results. The population of interest in this study was those less severely injured patients in which management decision is less straightforward due to a lack of immediate life-threatening injuries requiring either surgical or intensive care management. To date, no systematic review has been completed on this topic. A total of 28 studies were identified using a search strategy that met the criteria laid down in the PRISMA[34], MOOSE[47] and CRD[13] guidelines. The studies selected were assessed for their methodological quality which was found to be variable, but rather than exclude studies as a result of methodological issues, it was decided to include all studies and discuss any limitations.

Increasing age and its predictive value on mortality in trauma has been investigated in research extensively. Questions still remain regarding the exact age at which risk of mortality increases significantly and whether the increased mortality in the elderly is due to loss of physiologic reserve, or underlying co-morbidities common in the elderly. In this study, results suggest that an age of greater than 65 years is a risk factor for mortality in blunt chest wall trauma patients.[9,11,12,30,32,41,42,46] Two studies also reported that pre-morbid conditions, irrespective of age, were risk factors for mortality in blunt chest wall trauma patients.[9,11] Four other studies investigated the effect of pre-existing conditions on mortality in patients aged over 50 years[42] and 65 years or more.[3,7,17]

The number of rib fractures investigated as being a risk factor for mortality in blunt chest trauma patients varied between studies

Study or Subgroup	Pneumonia Events	Pneumonia Total	No pneumonia Events	No pneumonia Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Bergeron	18	49	31	336	33.6%	5.71 [2.87, 11.37]
Elmistekawy	3	7	4	32	5.5%	5.25 [0.84, 32.63]
Harrington	6	56	27	1072	16.1%	4.64 [1.83, 11.76]
Svennevig	21	96	29	556	44.8%	5.09 [2.76, 9.38]
Total (95% CI)		**208**		**1996**	**100.0%**	**5.24 [3.51, 7.82]**
Total events	48		91			

Heterogeneity: Chi² = 0.13, df = 3 (P = 0.99); I² = 0%
Test for overall effect: Z = 8.09 (P < 0.00001)

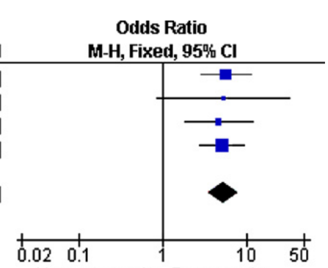

Fig. 5. Forest plot illustrating the odds of mortality with 95% confidence intervals for rib fracture patients who develop pneumonia.

however increased number of rib fractures has been shown to be associated with increased mortality. 'Three' is used as the critical number of rib fractures as the currently available risk stratification tools for blunt chest wall trauma are based on isolated anatomic findings of three or more rib fractures.[1] This should therefore be considered in the identification of high risk blunt chest trauma patients. Vital capacity was also investigated as a risk factor for mortality in blunt chest trauma patients however there is insufficient evidence currently in the literature to draw conclusions.[6]

Mortality as a result of pneumonia in trauma patients remains controversial. Five studies reported a significantly higher mortality in blunt chest trauma patients who developed pneumonia.[9,11,17,22,48] The effect of confounding was reduced in three of these studies as they excluded multi-trauma patients.[9,11,17] These results highlight the need for appropriate management of this patient population in order to minimise the on-set on pneumonia in the patient's recovery, including adequate analgesia and pulmonary hygiene.

Meta-analysis of only three of the risk factors for mortality following blunt chest trauma was possible as a result of an insufficient number of studies investigating the same risk factor and the variation between the study design and population investigated. Examination of the possible sources of heterogeneity highlighted marked differences in the cohorts investigated such as elderly patients only. Limited populations were used in the studies to minimise the effects of confounding, however they also serve to increase heterogeneity and limit reliable meta-analysis.

A retrospective study design may result in reduced reliability when compared with a prospective study, due to the inability to establish causation.[11,18] In the studies identified that used a trauma database for analysis, the exact cause of death may be attributable to causes unrelated to the blunt chest wall trauma. In addition, co-morbidities, nutritional and functional status of the patients on admission to the emergency department are rarely reported on trauma databases.[11] Database generation requires staff to complete data extraction from paper-based medical records, resulting in potential missing or erroneous data. As a result of the lack of uniform criteria and definitions, databases are subject to both selection and information bias.[18] Stawicki et al. considered another limitation of database analysis to be the lack of information on living wills and advanced directives.[46] A number of the included retrospective studies concluded that in order to further enhance the reliability of their results, a prospective study was required.[7,11,12,25,30,32,46]

A lack of referenced definitions for the independent and dependent variables was highlighted in the quality assessment which may have introduced information bias and furthermore affected the external validity and reproducibility of the studies and made cross-comparison of the studies questionable.[19] Only six of the studies defined mortality within a specific time frame. Complications frequently occur days after the initial chest injury.[3,42,43] Shorr et al. reported that elderly blunt chest wall trauma patients have an increased rate of deaths later than 48 h after admission.[42] A pre-specified time frame for mortality would therefore increase both reliability and external validity of the studies. A number of studies used the 9th Revision of the Clinical Modification of International Classification of Diseases codes to define or categorise the chest trauma suffered by the patient however the codes used differ between the studies.[11,30,32,37,46]

There was variation between the samples investigated in the studies. Some studies did not discuss power calculations therefore the results may lack the reliability of the studies with larger sample sizes. The quality assessment process considered whether the selected cohort was representative of the general blunt chest wall trauma population. A number of studies only investigated elderly patients[3,6,7,17,22] and one study investigated blunt chest wall trauma secondary to motor vehicle accident.[32] These studies were thought not to be representative of the general blunt chest wall trauma population, but were included in the study as they provided valuable information on a specific sub-group and needs further investigation.

The comparability of groups was examined. The selection of a comparable control group in an observational study is the most difficult decision facing the authors.[20] The difficulty exists in identifying two exact groups in terms of age, presence of co-morbidity, injury severity and respiratory or functional status on admission with the single difference being only the risk factor under investigation. In a number of the studies investigated, statistical adjustment for baseline differences in key variables was performed and reported at the analysis stage of the study.

The affect of confounding on the reliability of observational studies has been previously investigated. Smith and Phillips concluded that many of the associations identified in studies are due to confounding, often by factors which are difficult to measure.[45] Confounding was evident in the selected studies. A number of the studies in the review included patients with associated injuries or multi-trauma when studying blunt chest wall trauma patients. The patients could have suffered poorer outcomes as a result of a head or abdominal injury which were unrelated to the chest trauma. The studies that include patients with associated injuries however identify that the early deaths were primarily related to haemorrhagic shock, head or abdominal trauma in contrast to the later deaths which were reported to be caused by respiratory complications such as pneumonia, acute respiratory distress syndrome, sepsis or multi-organ failure.

The severity of the patient's injury also determines the level of pain experienced by the individual and consequently their management or treatment options. The management of pain following blunt chest wall trauma has been investigated in the literature and has been shown to significantly influence patient outcomes, thus potentially acting as confounding in the studies in this review. Similarly, the more severe the injury the more likely the patient may require mechanical ventilation as part of their management. Incidence of ventilator associated pneumonia is reported to be significant in patients requiring mechanical ventilation[18] which may act as confounding and influence patient outcomes following blunt chest wall trauma in the studies in this review.

A further possible source of confounding is the on-set of pneumonia following blunt chest wall trauma. This could be affected by the management of the patient not their age or number of rib fractures, as patients who require mechanical ventilation are at increased risk of ventilator associated pneumonia.[18] Reliability of the studies investigating the number of rib fractures as a risk factor for mortality may be affected as up to 50 percent of rib fractures are missed on chest radiograph.[14,50] In order for the studies to be reproducible, full definitions and explanations of all independent and dependent variables are required.[19]

Limitations

Systematic reviews of observational studies remain a contentious issue in research. Identification of potential forms of bias is important in observational studies, which are sensitive to publication bias and confounding. The results of this review are subject to publication bias as the studies with significant findings are more readily published in peer-reviewed journals than those without.[21] There is also a tendency amongst authors to only present significant results.[21,47] The search strategy included a number of methods to reduce publication bias but no unpublished studies investigating risk factors were identified in the search. As a result of the difficulty in negating the effects of bias and confounding in observational studies, it is important that the results of each individual study are interpreted with caution.

Conclusions

Patients who present with mild to moderate blunt chest wall trauma can normally be safely discharged from the emergency department with adequate pain control and education on pulmonary hygiene. A percentage of this patient group will develop late complications however no current guidelines exist to assist the emergency department physician in the recognition of this high risk blunt chest wall trauma patient population. In order to develop such guidelines or a risk stratification tool, the risk factors for mortality previously investigated in the literature need to be identified and summarised. In this systematic review, the risk factors for mortality in patients sustaining blunt chest trauma were a patient age of 65 years or more, three or more rib fractures, and the presence of pre-existing disease specifically cardiopulmonary disease. The development of pneumonia post injury was also a significant risk factor for mortality in patients with blunt chest wall trauma.

We recognise that the findings of this review are based on a small number of variable quality studies. However the meta-analysis results provide evidence to guide the clinician who decides to admit a blunt chest wall trauma patient who presents with no immediate life-threatening respiratory complications, but has a high risk of going on to develop respiratory failure. As a result of the variation in outcome measures used, the quality of the studies and lack of referenced definitions of independent variables used in the studies, the results of the selected studies should be interpreted with some caution. Further prospective studies are needed in order to fully validate the reported results of the selected studies for this review.

Conflict of interest statement

The three authors of this study state that they have no conflict of interest.

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