

REVIEW

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Treatments for blunt chest trauma and their impact on patient outcomes and health service delivery

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Abstract

Blunt chest trauma is associated with a high risk of morbidity and mortality. Complications in blunt chest trauma develop secondary to rib fractures as a consequence of pain and inadequate ventilation. This literature review aimed to examine clinical interventions in rib fractures and their impact on patient and hospital outcomes. A systematic search strategy, using a structured clinical question and defined search terms, was performed in MEDLINE, EMBASE, CINAHL and the Cochrane Library. The search was limited to studies of adult humans from 1990-March 2014 and yielded 977 articles, which were screened against inclusion/exclusion criteria. A hand search was then performed of the articles that met the eligibility criteria, 40 articles were included in this review. Each article was assessed using a quantitative critiquing guideline. From these articles, interventions were categorised into four main groups: analgesia, surgical fixation, clinical protocols and other interventions. Surgical fixation was effective in patients with flail chest at improving patient outcomes. Epidural analgesia, compared to both patient controlled analgesia and intravenous narcotics in patients with three or more rib fractures improved both hospital and patient outcomes, including pain relief and pulmonary function. Clinical pathways improve outcomes in patients ≥ 65 with rib fractures. The majority of reviewed papers recommended a multi-disciplinary approach including allied health (chest physiotherapy and nutritionist input), nursing, medical (analgesic review) and surgical intervention (stabilisation of flail chest). However there was a paucity of evidence describing methods to implement and evaluate such multidisciplinary interventions. Isolated interventions can be effective in improving patient and health service outcomes for patients with blunt chest injuries, however the literature recommends implementing strategies such as clinical pathways to improve the care and outcomes of these patients. The implementation of evidence-practice interventions in this area is scarce, and evaluation of interventions scarcer still.

Keywords: Rib fractures, Management interventions, Patient and health outcomes

Introduction

Blunt chest trauma is associated with a high risk of morbidity and mortality [1]. Rib fractures constitute a major part of blunt chest trauma and each additional rib fracture is associated with an increasing likelihood of developing complications [2,3]. Each additional rib fracture in the elderly population increases the odds of mortality by 19% and of developing pneumonia by 27% [3,4]. Respiratory complications develop with rib fractures

as a consequence of splinting of the thorax from pain and mechanical instability resulting in inadequate ventilation [5]. Even an isolated rib fracture is associated with significant consequences, particularly in the older population [6,7]. This causes decreased lung volumes, atelectasis, and may progress to pneumonia, respiratory failure, need for prolonged ventilation and possible death [8]. Moreover reduced mobility in blunt chest trauma increases the likelihood of venous thrombosis [9,10].

Management of blunt chest trauma focuses on a combination of effective analgesia, surgical fixation, chest physiotherapy, respiratory care and early mobilisation [11,12]. If rib fracture pain in blunt chest trauma is not treated in a timely manner, complications may result in

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death, long-term pulmonary impairment, increased hospital length of stay (LOS) and increased use of health-care resources [1]. Inadequate or delayed pain relief is well known to cause people to eat less, sleep poorly, undergo psychological stress, experience restricted movement, and be unable to participate in normal activities including work [13]. Although literature reviews exist for some specific interventions such as surgical rib fixation and epidural analgesia, there are no published reviews evaluating all potential treatment options for blunt chest trauma. The purpose of this review is to examine the literature around interventions in blunt chest trauma to prevent complications and death.

Review

Research question

To review the treatments for blunt chest trauma and their impact on patient and hospital outcomes. Each term is defined, using the population, intervention, comparison, outcome (PICO) framework [14], in Table 1.

Methods

An integrative review was conducted, which enabled the inclusion of a diverse range of study designs. The review process involved a search of the current literature, evaluation and categorisation of the data, and analysis of the groups [15]. A scoping search was conducted in the Medline Database to determine MESH terms appropriate to the research question. A search was conducted of the Cochrane, Medline, EMBASE and CINAHL databases in March 2014 using search terms including “thoracic injuries”, “rib fractures”, “mortality”, “pneumonia”, “outcome assessment” and “length of stay” [see Additional file 1: Tables S2 and S3] includes a full list of search terms and the databases searched. The initial search was performed without language restrictions or limitations to research design. The initial search was limited to studies of humans, adults and from 1990 onwards. This time-frame was chosen due to changes in interventions, including ventilation and surgical fixation based on a better understanding of blunt chest injury pathophysiology [16]. The initial search was limited to blunt chest trauma and did not focus on specific individual injury types. Patient outcomes included complications such as pneumonia, the duration of mechanical ventilation, pain level and mortality. Health service delivery referred to the

access to interventions and the provision of multidisciplinary care, delivery outcomes included cost and hospital length of stay.

The search yielded 1107 articles, of which 130 were duplicates. The remaining 977 titles and abstracts were inspected to determine if they fulfilled our preliminary inclusion criteria: (1) original research, (2) blunt chest trauma, including articles that enrolled a mixture of blunt and penetrating chest trauma, or polytrauma, (3) any intervention for the treatment of blunt chest trauma, (4) included a comparator, (5) contained measured outcomes, and (6) the abstract was in English. 65 potentially relevant articles were identified. The full text articles were then obtained and reviewed by each author to ensure all inclusion and exclusion criteria were met. One article was unable to be retrieved, as a full manuscript had not been published.

Articles were excluded if patient outcomes were primarily dependent on the speed and accessibility of advanced trauma surgical services, rather than on interventions aimed at preventing the complications of pain, immobility and respiratory impairment. For example articles evaluating patients with catastrophic injury requiring emergency thoracotomy were excluded due to the high rates of extra-thoracic injuries, and the low baseline survival rates [17,18]. 32 articles remained after review of the full text for eligibility criteria. A hand search was conducted of the reference lists of these articles and eight further articles were included. The screening process is highlighted in Figure 1 [19]. The 40 remaining articles were analysed and are summarised [see Additional file 2: Table S4]. Each article was assessed using a quantitative critiquing guideline [20] to assess the quality of the study. Secondly, using the US Preventive Services Task Force guidelines, the level of evidence was rated as good, fair or poor [21]. Evidence is rated based on parameters for evaluating the internal validity of the different study designs. A good study meets all criteria for that study design, a fair study does not meet all criteria but it has no fatal flaw that invalidates its results, and a poor study contains a fatal flaw [21]. Information extracted included level of evidence, patient group, outcomes, findings and limitations.

Results

The 40 reviewed articles originated from 12 different countries with varying health systems, including USA,

Table 1 PICO research terms [14]

Population	Adult - blunt chest trauma	Sternal fractures, rib fractures, blunt chest injury, thoracic injury,
Intervention	Multidisciplinary intervention	Models of care, management intervention, care practices, care protocols
Comparison	Other intervention	
Outcome	Patient and health outcomes	Mortality, pneumonia, pneumothorax, haemothorax, hospital length of stay, ICU stay, DVT, PE, costings, treatment outcome

ICU: Intensive care unit; DVT: deep venous thrombosis; PE: pulmonary embolism.

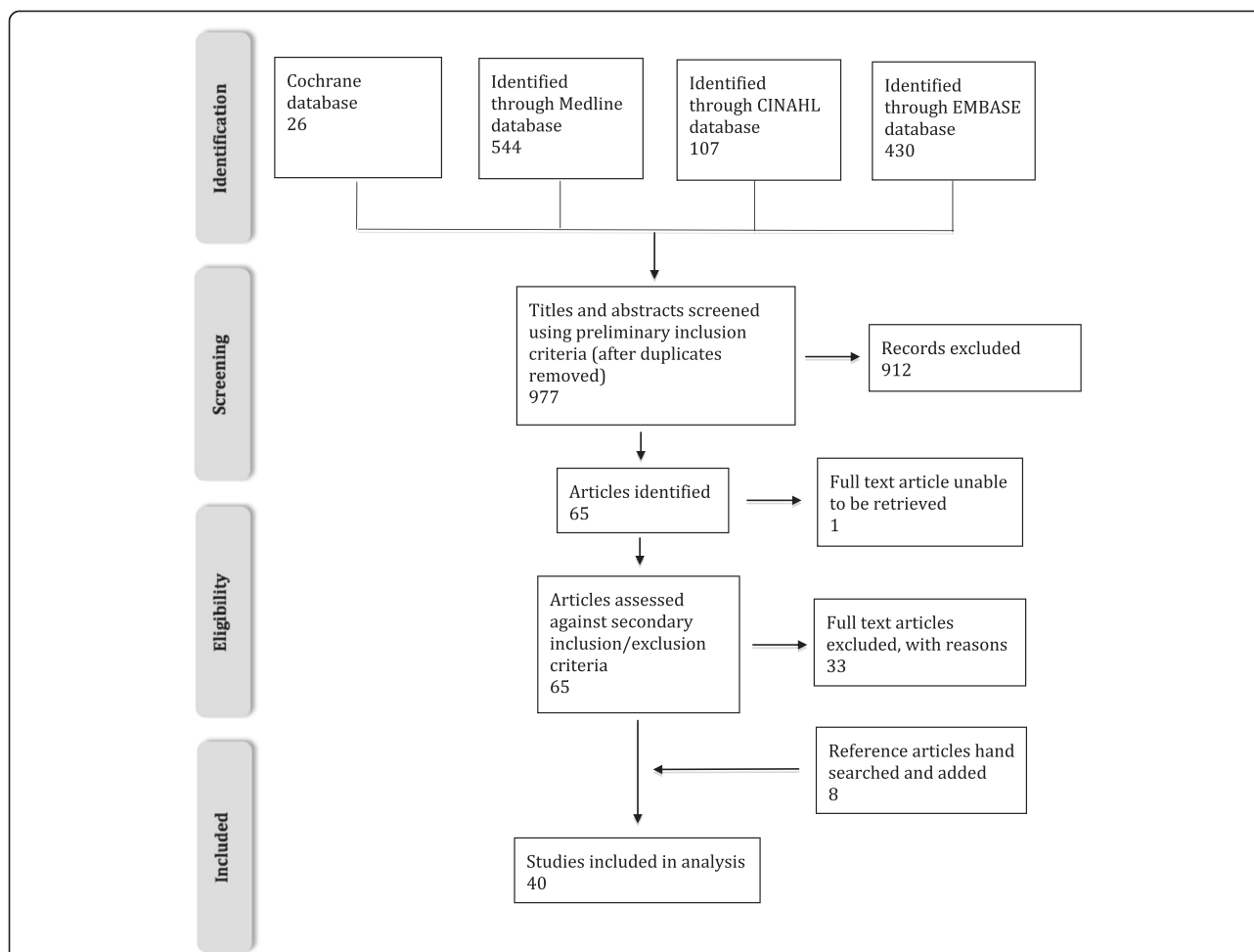


Figure 1 Prisma diagram representing the search and screen process [19].

Germany, Australia, Italy and Egypt. Research methods ranged from case series to randomised controlled trials. Using the critiquing guidelines for level of evidence, 7/40 articles were assessed as poor, 20/40 as fair and 13/40 as good.

The treatments for blunt chest trauma identified were grouped into four main categories: surgical stabilisation of rib fractures, analgesia for effective pain relief, the implementation of clinical protocols and multidisciplinary interventions, and other interventions, including ventilation and video assisted thoracoscopy surgery. The main outcome measures reported were ventilator dependent days, cost, complications including pneumonia, mortality, pain scores and hospital and intensive care unit length of stay (ICU-LOS). Surgical fixation was limited to patients with flail chest and the majority of analgesic modalities were in patients with three or more rib fractures following blunt chest injury. Multidisciplinary interventions (clinical pathways) were evaluated in patients 45 years and older with four or more rib fractures or patients 65 years and older with three or more rib fractures.

Surgical stabilisation

Flail chest, where at least three consecutive ribs are fractured in two or more places, compromises thoracic cage integrity and is associated with significant morbidity and mortality [22]. This is particularly true in the elderly, those with bilateral flail and patients with pulmonary contusion as it is associated with a higher rate of complications and a longer period of mechanical ventilation [23-26]. Surgical rib fixation (SRF) is a treatment for flail chest as it provides chest wall stability. Retrospective studies have noted a significant decrease in mechanical ventilation requirements after surgical fixation [22,25,27]. Through decreasing the time required on mechanical ventilation, surgical fixation prevents ventilator-acquired pneumonia [25,28], a common complication of prolonged intubation [24,25].

Three randomised trials provided the best evidence for the benefits of surgical rib fracture fixation. Surgical fixation was identified as a treatment for patients with flail chest requiring mechanical ventilation and is associated with a decrease in ICU-LOS, fewer days of mechanical

ventilation and cost savings compared to non-operative management [28-30]. Tanaka et al. [28] randomised 37 consecutive flail chest patients, intubated in emergency and requiring ventilation, to either surgical stabilisation or conservative internal pneumatic stabilisation. Internal pneumatic stabilisation involves providing positive end-expiratory pressure ventilation through intubation and mechanical ventilation or non-invasive ventilation devices. The surgical rib fixation group demonstrated decreased days of ventilator dependence, and shorter ICU-LOS [28]. There was a lower incidence of pneumonia, a higher return to full time work at six months, and less persistent pain at six and 12 months in those receiving surgery [28]. Granetzny et al. [29] and Marasco et al. [30] also found that patients who received surgical treatment had significantly fewer days of mechanical ventilation and a shorter hospital and ICU-LOS. The estimated cost savings ranged from USD 10,000 [28] to AUD 14,443 [30] per patient with surgical rib fixation as a result of the decrease in ICU-LOS [30]. None of the studies were large enough to draw conclusions on the effect of this intervention on thromboembolism and death.

Analgesia

Pain in blunt chest trauma is associated with restricted ventilatory function, which can lead to serious complications [5]. Multiple methods of analgesia have been evaluated and compared in the rib fracture population, including non-steroid anti-inflammatory medications, epidural catheters, intravenous narcotics, patient controlled analgesia (PCA), lidocaine patches, intercostal blocks and paravertebral blocks [8,12,31-36].

The most predominate mode of analgesia reported was epidural catheters. The available evidence for patients with three or more rib fractures suggests that epidural analgesia provides more effective pain relief in comparison with other analgesic modalities, and it is most applicable to patients with functional respiratory compromise secondary to pain [3]. There was less evidence for patients with one or more fractured ribs, and studies were limited to > 65 years, however, retrospective studies suggest that patients given epidural analgesia compared to IV narcotics reduces mortality [37].

Comparing epidural analgesia with intravenously administered opioids or patient controlled analgesia, Mackersie et al. [32] and Bulger et al. [38] in randomised controlled trials respectively reported that epidural analgesia was associated with a mild improvement in pulmonary mechanics, and reduced rates of pneumonia and the duration of mechanical ventilation. In two retrospective cohort studies, Gage et al. [11] with 836 patients and Wisner et al. [37] with 307 patients, showed that epidural analgesia was associated with a reduction in short and long term mortality compared to those using other analgesic

modalities. Compared to PCA, epidural analgesia is associated with lower pain scores [36,39], however, as PCA pain control is reliant upon a degree of patient understanding in how to deliver their analgesia, higher pain scores in the PCA group may indicate the importance of patient selection when choosing PCA [36,39]. In a trauma patient with fractures, epidurals can be technically difficult to place, and are contraindicated in patients with coagulopathy [31]. Additionally, epidural catheters are associated with a number of complications including headache, respiratory depression, infection, neurological injury and epidural haematoma [40].

Two other analgesic techniques include lidocaine patches and intercostal and paravertebral blocks. Lidocaine patches involve placing an adhesive patch containing 5% lidocaine directly over the site of injury/pain [41]. When evaluated in a randomised double-blind, placebo controlled trial of 58 patients, no improvement in pain control or hospital length of stay could be demonstrated [35]. Whilst lidocaine patches are easy to use and are fairly benign, they may offer little or no pain control, and further research is necessary before they can be recommended as an adjunct for pain control in this setting. Paravertebral and intercostal nerve blocks improved pain scores at rest and on coughing compared to the initial treatment [31,34,42]. However, neither nerve block was evaluated directly with an alternate analgesic technique such as epidurals or PCA.

Larger randomised controlled trials comparing epidural analgesia with intravenous narcotics, patient controlled analgesia and nerve blocks are required to draw a firm conclusion on the overall effectiveness of epidural analgesia. Current limitations exist, particularly due to the small sample size in a number of studies [32,38], meaning that the rare but severe complications are not examined.

Clinical pathways

Rib fracture clinical pathways were first documented by Sesperez et al. in 2001 [43], and aim to streamline patient care and provide guidelines for the different interventions required in rib fracture treatment. The four clinical pathways that have been evaluated in the literature, show an improvement in patient and hospital outcomes post protocol introduction, by reducing patient complications and hospital costs [43-47]. These pathways have been shown to be applicable in patients with ≥ 1 fractured rib [43] and improve outcomes in patients ≥ 65 with one or more rib fractures [46].

A multidisciplinary pathway improved outcomes for patients and decreased ICU and Hospital LOS, pneumonia and mortality [47]. This pathway applied to patients greater than 45 with four or more rib fractures and involved the pain service for analgesia review, respiratory team for medical care, physiotherapy for deep breathing exercises, nutritionist to monitor the nutritional status of patients

and nurse practitioner to ensure continuity of care. Patients on this pathway were given significantly more aggressive pain management, including prescription of PCA and epidural catheters, which could account for the improvement in outcomes [47]. Two other clinical protocols demonstrated a decrease in hospital LOS [46] and emergency department re-attendance in the post-implementation period of this protocol [45].

Adrales et al. [48] examined a practice guideline for thoracostomy tubes, showing that post-implementation of the practice guideline, there were less chest radiographs and fewer days of thoracostomy tubes. However, contrary to the guidelines, 26% of patients received more than the recommended 24 hours of antibiotic therapy and 45% had chest radiographs before thoracostomy tube removal. This suggests the difficulties in implementing and complying with clinical guidelines.

Other interventions

The treatment of rib fractures includes primary modalities such as surgical rib fixation, analgesia and ventilation, as well as secondary treatments for complications such as thoracostomy tubes and video-assisted thoracoscopic surgery.

Ventilation is an important treatment modality for rib fracture management in order to mitigate shallow breathing associated with rib fractures [49,50]. Bolliger et al. [49] and Walz et al. [50] compared CPAP to endotracheal intubation and mechanical ventilation, demonstrating that patients treated with CPAP had a shorter stay in ICU and hospital, and developed significantly fewer complications. Incentive spirometry, to promote deep breathing, was shown by Shukla et al. to reduce morbidity [42]. In order to be effective, both CPAP and spirometry require adequate analgesia [51].

For the treatment of a persistent pneumothorax or haemothorax after blunt chest injury, video-assisted thoracoscopy surgery (VATS) has been developed [52]. Fabbrucci et al. [52] compared patients with only a chest tube to patients with a chest tube and VATS. Their results were inconclusive, for whilst both groups had similar recovery time, the two groups had different levels of injury severity. Smith et al. [53] compared patients who received VATS ≤ 5 days after injury and > 5 days after injury. Patients treated ≤ 5 days after injury had a lower rate of conversion to an open procedure and a lower overall hospital LOS. Both these studies suggest that VATS is an effective procedure for treating complications of blunt thoracic injury [52,53].

Discussion

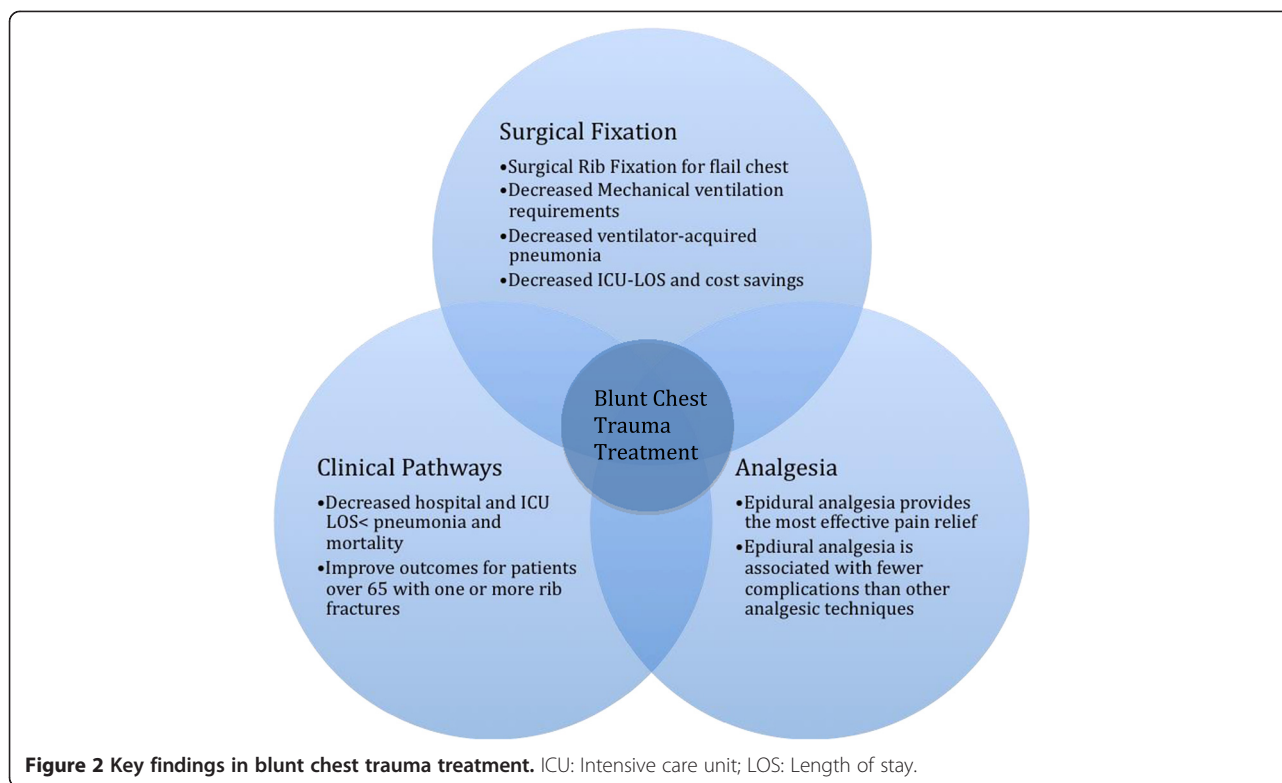
Blunt thoracic trauma has a significant impact on morbidity and mortality when left untreated [1]. Many different treatment modalities are used to reduce the complications

associated with rib fractures, however, their efficacy is often unclear. This literature review provides a comprehensive examination of the different treatment modalities involved and their individual and relative effectiveness. The key findings of this review are highlighted in Figure 2. The results show that analgesia, particularly in the form of epidurals, surgical fixation and ventilation are single modal interventions effective at improving outcomes. However, difficulties exist in ensuring that patients receive a full spectrum of care, hence clinical pathways have been developed in order to organise this care for the patient. The findings of this review are limited by the quality of evidence. Only 10 of the 40 articles were prospective randomised trials. Most trials were limited by small sample size, and by selection bias in retrospective studies. A summary of each treatment option and the strength of the surrounding literature is illustrated [see Additional file 3: Table S5].

Evolution of interventions

The literature describing rib fracture treatment has developed from the delivery of single modal interventions to broader multidisciplinary care, encompassing multiple interventions. In the past, rib belt treatments were popular for the treatment of rib fractures [54]. However, their use has been superseded by improvements in ventilation and surgical fixation [31]. Due to the development of positive pressure ventilation in the 1950s, mechanical ventilation became a mainstay in the treatment of rib fractures [55]. Due to the increasing evidence of the association of intubation and mechanical ventilation with complications including pneumonia and death [56], less invasive forms of respiratory support have been developed [57,58]. Despite association with increased complications, mechanical ventilation is applicable for patients with flail chest and severe concomitant injuries or patients with persistent respiratory compromise or failure after sufficient analgesia [59]. Surgical fixation has had a recent increase in interest particularly in the treatment of flail chest, where it seems to improve outcomes [28-30]. However, its broader application is limited by the difficulties in defining appropriate population groups for treatment and the current low incidence of rib fixation in trauma centres [22,60].

Chest physiotherapy, including incentive spirometry, and CPAP have decreased complications in rib fracture treatment [31,50,61]. This literature review returned limited evidence into the role of chest physiotherapy and allied health in the outcomes of patients with blunt chest trauma and primarily focused on patients with multiple rib fractures. Rib fractures are reported to be the most common clinical fracture in older people [62], and this demographic is the most at risk of rib-fracture-related morbidity [7,63-65]. Rapid mobilisation through physiotherapy is considered a key factor in preventing complications,



including pneumonia, respiratory failure and ARDS [65]. However to facilitate these interventions, effective pain control is necessary to allow for deep breathing chest physiotherapy and improved lung function [66]. Further evidence is required in determining the effectiveness of combining therapies, including mobilisation, respiratory care and pain management [5,61]. Additionally, patient outcomes are impacted by other treatment interventions, particularly in the polytrauma patient, such as fluid resuscitation [67]. Consideration needs to be made by multidisciplinary teams for the impact of other therapies on blunt chest trauma.

The literature recommends implementing clinical pathways to coordinate trans-disciplinary interventions, improve compliance with recommended treatment and ensure consistency in the delivery of interventions [43]. Successful clinical pathways standardise practice, translate research into practice and improve inter-professional co-ordination [68]; and they are known to improve patient and health service outcomes across a number of other clinical conditions, such as planned knee replacement surgery [69], stroke and heart failure [70]. An important limitation of clinical pathways can be an inflexibility for tailoring care to individual patient's needs [71]. For example, eligibility for a pathway require a certain number of ribs to be demonstrably fractured, but we know more than 50% of rib fractures cannot be seen on x-ray [72]. Particularly amongst the elderly, the physiologic

consequences of clinically apparent rib fractures may be very similar whether or not a fracture is radiologically visible, and so should be considered for inclusions in these pathways. The evaluations have been limited to the effectiveness of the pathway as a whole, rather than the clinical interventions within the pathway that may contribute to improved outcomes. Todd et al. [47] suggested that the aggressive use of the pain service was integral to the benefits elicited in the post-pathway group, while Sahr et al. [46] attributed the benefits to the ability of the trauma team to coordinate multidisciplinary care. Further research is required to determine which aspects of the clinical pathways are effective at improving patient outcomes.

Implementing interventions and organising patient care

To ensure that clinical pathways are effectively implemented, continual reinforcement and education are required to ensure the pathways are activated [43]. There are many barriers to the implementation of multidisciplinary care pathways including reluctance to change and lack of suitable existing evidence for their implementation [73]. As a variety of interventions are effective in treating rib fractures involving multiple medical and allied health disciplines, to ensure coordination, implementation, monitoring and evaluation of recommended care, an organised system is required. One such model is the trauma nurse case manager, which is known to be effective at reducing complications and improving the time to allied health

interventions [74]. Trauma case managers are integral to facilitate the achievement of outcomes and reinforcing the implementation of clinical pathways [43]. Other forms of organising patient care include multidisciplinary rounds, whereby medical, surgical and allied health professionals meet to discuss patient care. These have also been shown to decrease hospital length of stay and streamline the care of trauma patients [75].

This review has highlighted the need for the delivery of multidisciplinary interventions such as a “care bundle”. “Care bundles” are a uniform set of evidence based practices specific to a clinical presentation that is considered by the attending team [76]. A “care bundle” for blunt chest trauma could be comprised of oxygen therapy, physiotherapy, analgesia and trauma care coordination. In determining patients eligible for a “care bundle” consideration needs to be made of the presence of lung injury, concomitant injuries, age, number of rib fractures and underlying respiratory disease [77,78].

Sources of further literature

Similar pulmonary complications exist between rib fractures in cardiothoracic surgery and rib fractures following blunt chest trauma [79]. Lawrence et al. [79] in a systematic review analysed interventions to prevent postoperative complications after non-cardiothoracic surgery. A synthesis of 16 studies concluded that lung expansion interventions (for example, incentive spirometry, deep breathing exercises and continuous positive airway pressure) reduce pulmonary postoperative complications. These results are similar to those in rib fracture interventions [50,62]. Cohn et al. [80] supports the role of clinical pathways, demonstrating that for all uncomplicated cardiac surgery patients, a clinical pathway reduces costs and hospital LOS in patients undergoing cardiac surgery. Review and adaptation of interventions after cardiothoracic surgery may add to the knowledge base of treatments in blunt chest trauma.

Limitations

There was no literature included in this review on physiotherapy and high flow nasal prongs, despite both treatments being a mainstay in rib fracture management [81,82]. Other ventilation treatments including CPAP had limited evidence, and a comparison and definition of the appropriate CPAP and HFNP patient is required. Further randomised controlled studies are required into patient controlled analgesia and other analgesic techniques such as nerve blocks. Additionally, further research is needed into clinical pathways that take into account a greater number of risk factors [63,64].

Conclusion

A broad amount of literature exists surrounding interventions in blunt chest trauma. The three treatment

modalities that have significant evidence for their benefits are surgical rib fixation, epidural analgesia and transdisciplinary clinical pathways. Collectively, these improve hospital outcomes including ICU and hospital LOS as well as patient outcomes including mortality and morbidity in patients with blunt chest trauma. Systems that address each component of multidisciplinary care and ensure their implementation would benefit patient and hospital outcomes. Further evidence is required in determining the effectiveness of combining therapies, including mobilisation, respiratory care and pain management.

Additional files

Additional file 1: Table S2. Search Strategy used in database search.
Table S3. Summary of literature searched.

Additional file 2: Table S4. Overview of the Studies.

Additional file 3: Table S5. Summary of each treatment option and strength of the literature [83-88].

Abbreviations

ICU: Intensive care unit; LOS: Length of stay; IV: Intravenous; ISS: Injury severity score; SRF: Surgical rib fixation; PCA: Patient controlled analgesia; PE: Pulmonary embolism; CPAP: Continuous positive airway pressure; VATS: Video assisted thoroscopic surgery.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

AU performed the review of the literature and drafted the manuscript. KC and SEA designed the study and revised the manuscript. All authors read and approved the final manuscript.

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