Scientific review

I. MANAGEMENT OF MULTIPLE RIB FRACTURES AND FLAIL CHEST

Flail chest is the paradoxical movement of a segment of chest wall caused by fractures anteriorly and posteriorly within three or more adjacent ribs, which can derange respiratory function. The paradoxical motion of the flail segment is usually limited by surrounding structural components, and principally the intercostal musculature. Underlying cardiopulmonary disease and injury contributes to the physiologic perturbations to respiration caused by the flail segment.

KMQ-1. What is the optimal analgesic management in multiple rib fractures and flail chest?

Epidural Analgesia

- Recent studies show epidural analgesia is associated with significantly lower mortality compared to non-epidural analgesia in patients with chest trauma.[6, 7]
- Findings in the literature are mixed with regard to the benefits of epidural analgesia on morbidity, length of stay ICU and hospital, and duration on mechanical ventilation in patients with chest trauma:
    - A randomized trial found a 6-fold increased risk of pneumonia and two-fold increase in ventilator days in patients with ≥3 rib fractures receiving IV opioids compared to those receiving epidural analgesia.[8]
    - Meta-analyses found epidural analgesia does not significantly affect mortality, length of stay in ICU and hospital, or duration of mechanical ventilation.[1, 9, 10] One of these studies found that combining epidural analgesia with local anaesthetics resulted in decrease in days on mechanical ventilation.
    - Recently, a large registry study comparing epidural analgesia and paravertebral block showed no difference in length of stay in ICU or hospital, duration of mechanical ventilation, or development of pneumonia. Patients who did not receive any regional analgesia had longer length of stay and more frequent ICU admissions.[11]
    - A multi-centre retrospective study (n=836) found no difference in pneumonia, empyema, reintubation, or pulmonary embolism between epidural and non-epidural analgesia.[7]
- Meta-analysis by EAST shows epidural analgesia produced lower pain results at 24 and 48 hours but not at 72 hours in patients with chest trauma.[1]
- Epidural analgesia requires technical competence and monitoring to avoid and manage complications which include: dural puncture, spinal cord injury, hypotension, cardiac arrest, urinary retention, pruritus, headache, infection, hematoma, and motor block limiting mobility.[12, 13]

Patient-Controlled Analgesia

- A randomized study showed the IV patient-controlled analgesia to be inferior to paravertebral block in reducing pain (at rest and during coughing) and improving pulmonary function in patients with chest trauma, as well as having a higher incidence of complications ($p<0.05$).[14]
- In the context of multimodal pain management, while oral opioids are preferred to intravenous administration, patient-controlled analgesia should be used if IV is required in patients with chest trauma.[15]
- A small, randomized study (n=60) found improved arterial oxygenation function and accelerated recovery of pulmonary function in patients with chest trauma receiving ultrasound-guided patient-controlled paravertebral block compared to those on patient-controlled IV analgesia.[15]

Intercostal Block

- There are no randomized controlled trials or meta-analyses available on this topic.
- A single site prospective study (n=102) found significant improvements in pain, respiratory rate ($p<0.05$) and shorter average length of stay in hospital (2.9 days vs. 5.9 in historical control) in patients receiving continuous intercostal nerve block (0.2% ropivacaine infusion), with no complications.[16]
- A small retrospective study (n=54) found dramatic decrease in pain immediately following administration of the intercostal nerve block compared to controls ($p=0.007$) but the pain control effects decreased over time (no significant difference observed 1 day and 7 days after procedure).[17] The authors suggest combining intercostal blocks with other modalities to manage pain.
- Intercostal blocks require an injection at the level of the fracture and one above and below. Multiple rib fractures thus require several injections, presenting potential risk of pneumothorax and local anesthetic toxicity.[14]

Additional Analgesic Options

- A double-blind RCT (n=36) comparing IV lidocaine with usual analgesic and placebo showed a significant reduction in pain with movement in patients with two or more traumatic rib fractures.[18] A retrospective study (n=89) over a 5-year period compared IV lidocaine with epidural analgesia for traumatic rib fractures and found similar reductions in pain scores, with potential opioid-sparing effect for IV lidocaine compared.[19] These findings suggest that IV lidocaine may be considered as an analgesic modality.

EXTERNAL RECOMMENDATIONS

RECOMMENDATIONS	COMMENTS
1. The panel recommends that clinicians offer multimodal analgesia, or the use of a variety of analgesic medications and techniques combined with nonpharmacological interventions, for the treatment of postoperative pain in adults. [APS — Strong recommendation, high-quality evidence]	Adopted and combined with EAST/TAS statement (#2 below) to create Recommendation A.
2. In patients with blunt thoracic trauma, we conditionally recommend the use of multimodal analgesia versus opioids alone to improve analgesia and patient outcomes [EAST/TAS 2016 — low quality evidence]	Adopted and combined with AP statement (#1 above) to create Recommendation A.
3. In patients with blunt thoracic trauma, we conditionally recommend the use of epidural analgesia versus opioids alone to improve analgesia and patient outcomes. [EAST/TAS 2016 — very low quality evidence]	Implicit in Recommendation A.
4. There is insufficient evidence to prove the effectiveness of paravertebral analgesia in the trauma population. However, this modality may be equivalent to epidural analgesia and may be considered in certain situations when epidural is contraindicated. [EAST 2012 — Level 3]	Incorporated as optional regional anesthesia (Recommendation E).

KMQ-2. What is the optimal non-analgesic management of multiple rib fractures and flail chest?

Multidisciplinary Care of Multiple Rib Fractures and Flail Chest

- Important in managing multiple rib fractures is respiratory therapy involving aggressive pulmonary hygiene, as well as lung expansion (via incentive spirometry and positive expiratory pressure therapy devices) and secretion clearance (via vibratory mechanisms, coughing and airway suctioning) to prevent pneumonia and respiratory complications.[15] Standardizing these therapies into a multidisciplinary management protocol has been shown to improve patient outcomes.
- Case — Houston, Texas:[20]
  - **Protocol:** Patients age ≥45 years with >4 rib fractures were admitted to a monitored bed (intermediate or intensive care unit). Patients received patient-controlled analgesia and incentive spirometry upon admission and are evaluated for pain, inspiratory volume (≥15 mL/kg) and cough for the first 3 days. Patients who failed one or more of the above 3 criteria in the first 3 days entered into multidisciplinary clinical pathway:
    1. Pain consult (oral, IV and epidural analgesia) (Note: Do not start LMWH prior to pain consult. If they have been started, they must be withheld 24 hours prior to epidural)
    2. Respiratory therapy consult
    3. Physical/occupational therapy consult (optimize mobility)
    4. Nutrition consult
    5. Nurse Practitioner assessment
    6. Patients who entered into a multidisciplinary clinical pathway passed all 3 entrance criteria on 3 consecutive days, they were removed from the pathway.
  - **Results:** decreased ICU length of stay by 2.4 days (p=0.01) and hospital length of stay by 3.7 days (p=0.02), as well as decrease in pneumonia and mortality.

EXTERNAL RECOMMENDATIONS

RECOMMENDATIONS	COMMENTS
1. Obligatory mechanical ventilation in the absence of respiratory failure solely for the purpose of overcoming chest wall instability should be avoided [EAST 2012 — Level 2]	Adopted (Recommendation L)
2. The use of optimal analgesia and aggressive chest physiotherapy should be applied to minimize the likelihood of respiratory failure and ensuing ventilatory support. [EAST 2012 — Level 2]	Incorporated into Recommendations I and J
3. Self-activating multidisciplinary protocols for the treatment of chest wall injuries may improve outcome and should be considered where feasible. [EAST 2012 — Level 3]	Incorporated into Recommendation K

KMQ-3. What is the indication for surgical stabilization in the setting of multiple rib fractures or flail chest?

Surgical fixation of flail chest

- **Indications:** All possible indications are considered relative (not absolute) due to limited evidence. A large number of studies accept flail chest as an indication for surgical fixation but the quality of evidence is low.[5, 15] Multiple severely (bicortical) displaced fractures, significant chest wall deformity, and inadequate pain control have also been suggested as possible indications for acute surgical fixation.[15, 21]
- **Contraindications:** Pulmonary contusion and severe brain injury have been reported to result in poor outcomes[22, 23] but stronger evidence is needed.[16, 23] Other contraindications include respiratory failure not related to chest wall injury, spine instability, other injuries requiring prolonged intubation, and patient unable to tolerate surgery.[15]
- The majority of published studies involve ventilated patients and data on the management of non-intubated patients is lacking.[15]

Effect of surgical fixation on survival, ICU length of stay, duration on mechanical ventilation, hospital length of stay, and chronic pain

- Only three studies compare surgical fixation with non-operative multidisciplinary management, the latter involving multimodal analgesia, chest therapy, pulmonary toileting, and positive pressure ventilation, with opposing results.
    - Pieracci and colleagues[24] found the operative group had a significantly lower likelihood of both respiratory failure (76%) and tracheostomy (82%), shorter duration of ventilation (by 5 days), and higher median daily spirometry value (by 250 mL). [Note: This study included injuries beyond flail chest]
    - Farquhar and colleagues[25] found significantly better outcomes for non-operative multidisciplinary management for ventilator days (3.1 vs. 6.1 days, p=0.012), length of stay in the intensive care unit (3.7 vs. 7.4 days, p=0.009), total hospital length of stay (16.0 vs. 21.9 days, p=0.044) and rates of pneumonia (22% vs. 63%, p=0.004).
    - Beks and colleagues[26] found no significant advantage for surgical fixation of rib fractures (≥3 rib fractures) compared to non-operative management. Rib fixation was not associated with improved intensive care length of stay for flail chest patients, nor with hospital length of stay for multiple rib fracture patients. The authors
- **Long-term benefits:** A prospective study showed patients receiving surgical fixation of rib fractures progressively improved in pain, mobility activity, quality of life, lung function, and disability during the first operative year.[27] Another prospective controlled trial (combining randomization and observation) comparing surgical fixation (within 72 hours) with non-operative management in patients with rib fractures (≥3 ipsilateral, severely displaced rib fractures) but no flail chest found at 2-week follow-up significantly lower numeric pain score, improved quality of life, and lower pleural space complications, as well as a lower trend in narcotic consumption, in the surgical group.[28]

EXTERNAL RECOMMENDATIONS

RECOMMENDATIONS	COMMENTS
1. Surgical stabilization of rib fracture (SSRF) should be considered in all patients with flail chest. [Colloquium — Level 2b, Grade B] SSRF should be considered in patients with multiple, severe (bicortical) displaced fractures. [Level 4, Grade C]	Combined into Recommendation A.
2. SSRF should be considered in patients who fail early, optimal non-operative management, regardless of radiographic fracture pattern. [Colloquium — Level 5, Grade D]	Modified into Recommendation B, due to evidence supporting the benefits of surgical stabilization reducing duration on mechanical ventilation and ICU stay (see Additional Literature Support below).
3. Pulmonary contusion should not be considered an absolute contra-indication to SSRF; patients with pulmonary contusion should be evaluated for SSRF on an individual case basis. [Colloquium — Level 5, Grade D, i.e., lowest quality of evidence and strength of recommendation] Traumatic brain injury should not be considered an absolute contraindication to SSRF; patients with TBI be evaluated for SSRF on an individual case basis. [Level 5, Grade D, i.e., lowest quality of evidence and strength of recommendation]	Not included, as strong evidence is lacking (see Additional Literature Support below). Clinicians outside lead trauma hospitals should initiate tele-conferencing through Patient Transfer Network (PTN) (see Recommendation A under **TRANSFER TO HIGHER LEVEL OF CARE**).
4. We conditionally recommend operative rib ORIF compared to nonoperative management, to decrease mortality; shorten duration of mechanical ventilation, ICU length of stay (LOS), and hospital LOS; incidence of pneumonia, and need for tracheostomy. [EAST 2022 — low quality evidence]	See Recommendation A — the SAG recommends assessing the patient, via tele-conference consultation if needed, for the optimal management of rib fractures/flail chest.
5. Although improvement has not been definitively shown in any outcome parameter after surgical fixation of flail chest, this modality may be considered in cases of severe flail chest failing to wean from the ventilator or when thoracotomy is required for other reasons. The patient subgroup that would benefit from early "prophylactic" fracture fixation has not been identified. [EAST 2012 — Level 3]	Modified into Recommendation B.

KMQ-4. What are the imaging requirements for surgical stabilization of rib fractures?

2D versus 3D CT for preoperative planning in flail chest

- No study has yet compared the two CT imaging modalities in terms of their impact on preoperative planning for flail chest.[4]
- CT chest with 3D reconstruction has been suggested for preoperative planning to assist with fracture identification, selection of fractures for fixation, and assessment of pleural space.[16]

KMQ-5. What is the optimal timing within which acute rib fixation should be accomplished?

Benefits of early surgical fixation of rib fractures

- A prospective controlled multi-centre study suggests surgical stabilization of rib fractures within 1 day of admission. Each additional hospital day before surgical fixation was associated with increased likelihoods of pneumonia (31%), prolonged mechanical ventilation (27%), and tracheostomy (26%).[29]
- Most recent studies have performed surgical fixation with 72 hours of injury.[26, 27, 30, 31]
- Other benefits of early surgical fixation include less inflammation and callous formation, an early opportunity to evacuate the pleural space and place directed analgesia catheters, and less likelihood of further displacement.[4, 16]
- **Contraindications** to early fixation: Hemodynamic instability, other higher priority injuries (such as spine fractures and pulmonary contusion), and limited trial of non-operative management.[4]

EXTERNAL RECOMMENDATIONS

RECOMMENDATIONS	COMMENTS
1. Surgical stabilization of rib fractures should take place within 72 hours of injury. [Colloquium – Level 5, Grade D, i.e., lowest quality of evidence and strength of recommendation]	Adopted, see Recommendation A.

II. PULMONARY CONTUSION

Pulmonary contusion is often associated with chest wall trauma. It may not be noted on the initial chest X-ray. The clinician should be aware that respiratory status may decline over the first 24–48 hours post-injury.

KMQ-6. What is the optimal management of pulmonary contusion?

EXTERNAL RECOMMENDATIONS

RECOMMENDATIONS	COMMENTS
1. Patients with pulmonary contusion/flail chest (PC-FC) requiring mechanical ventilation should be supported in a manner based on institutional and physician preference. [EAST 2012 — Level 2]	Adopted, with added wording around transfer indications (see Recommendation A)
2. Steroids should not be used in the therapy of pulmonary contusion. [EAST 2012 — Level 2]	Adopted (Recommendation C)
3. A trial of mask CPAP/BIPAP may be of benefit in alert, compliant patients with marginal respiratory status in combination with optimal regional anesthesia. [EAST 2012 — Level 3]	Adopted, with added link to optimal analgesia management in this document (Recommendation B)
4. Independent lung ventilation may be considered in severe unilateral pulmonary contusion when shunt cannot be otherwise corrected owing to maldistribution of ventilation or when crossover bleeding is problematic. [EAST 2012 — Level 3]	Out of scope
5. High-frequency oscillatory ventilation (HFOV) should be considered for patients failing conventional ventilatory modes. [EAST 2012 — Level 3]	Out of scope
6. Diuretics may be used in the setting of hydrostatic fluid overload as evidenced by elevated pulmonary capillary wedge pressures in hemodynamically stable patients or in the setting of known concurrent congestive heart failure. [EAST 2012 — Level 3]	Out of scope

III. TRANSFER TO HIGHER LEVEL OF CARE

KMQ-7. What are the considerations for transfer to higher level of care (HLOC) of flail chest?

No relevant clinical scientific information identified.