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In patients with acute flail chest does surgical rib fixation improve outcomes in terms of morbidity and mortality?

Katharina Schulte[a,b], Donald Whitaker[a] and Rizwan Attia[a,*]

[a] Department of Cardiothoracic Surgery, King's College Hospital, London, UK
[b] Department of General, Visceral and Vascular Surgery, Minimally Invasive Surgery, St. Hedwig Hospital, Berlin, Germany

* Corresponding author. Department of Cardiothoracic Surgery, King's College Hospital, London SE5 9RS, UK. Tel: +44-020-32993871; fax. +44-020-32993433; e-mail: rizwanattia@doctors.org.uk (R. Attita).

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Abstract

A best evidence topic in cardiothoracic surgery was written according to a structured protocol. The question addressed was: In patients with acute flail chest does surgical rib fixation improve outcomes in terms of morbidity and mortality? Using the reported search criteria, 137 papers were found. Of these, 11 papers ($N = 1712$) represent the best evidence to answer the clinical question, and include one meta-analysis, two randomized, controlled trials (RCTs), five retrospective cohort studies and two case–control series. In-hospital mortality was lower for the surgical group in the meta-analysis [$n = 582$, odds ratio (OR) 0.31 (0.20–0.48), risk difference (RD) 0.19 (0.13–0.26), number needed to treat (NNT) 5] as well as significant decreases in ventilator days [mean 8 days, 95% confidence interval (CI) 5–10 days] and intensive care unit stay (mean 5 days, 95% CI 2–8 days). A reduction was found for septicaemia [$n = 345$, OR 0.36 (0.19–0.71), RD 0.14 (0.56–0.23), NNT 7], pneumonia [$n = 616$, OR 0.18 (0.11–0.32), RD 0.31 (0.21–0.41), NNT 3, $P = 0.001$], tracheostomy (OR 0.06, 95% CI 0.02–0.20) and chest wall deformity [$n = 228$, OR 0.11 (0.02–0.60), RD 0.30 (0.00–0.60), NNT 3]. Eight studies ($n = 1015$) had a shorter duration of mechanical ventilation following surgery. A reduction in intensive care unit stay was demonstrated in four papers ($n = 389$, 3.1–9.0 days), whereas a further three papers described a reduction in the duration of hospitalization ($n = 489$, 4–10.6 days). Three studies ($n = 166$) showed a lower risk for tracheostomy. One retrospective cohort study estimated lower total treatment costs in surgically treated patients ($32 300 vs $37 100) although not statistically significant. One retrospective case–control study described a lower risk for reintubation ($n = 50$, $P = 0.034$) and home oxygen requirements ($n = 50$, $P = 0.034$). One cohort study showed a better APACHE II score 14 days after trauma in the surgical group ($P = 0.02$). Surgical stabilization of flail chest in thoracic trauma patients has beneficial effects with respect to reduced ventilatory support, shorter intensive care and hospital stay, reduced incidence of pneumonia and septicaemia, decreased risk of chest deformity and an overall reduced mortality when compared with patients who received non-operative management.

Keywords: Acute flail chest • Surgery • Management • Rib fixation • Morbidity • Mortality

INTRODUCTION

A best evidence topic in cardiothoracic surgery was written according to a structured protocol. This is fully described in *Interactive CardioVascular and Thoracic Surgery* [1].

THREE-PART QUESTION

In [patients with acute flail chest] does [surgical rib fixation] improve outcomes in terms of [morbidity and mortality]?

CLINICAL SCENARIO

You are a trainee placed in a regional trauma centre. The intensive care team refers a patient with acute flail chest, pulmonary contusion and pelvic fracture after a road traffic accident. You are asked to evaluate the patient to see if it would be worthwhile fixing the patient's flail chest. You are unsure if surgery in the acute trauma setting would be beneficial for this patient versus conservative management with ventilation strategies. You decide to look up the literature on the topic.

SEARCH STRATEGY

OVID MEDLINE® 1946 to January 2016 was searched using the following terms: [rib fractures] OR [flail chest] OR [costal fracture] OR [flail thorax] AND [operative] OR [surgery] OR [fixation] AND [outcome] OR [outcomes].

SEARCH OUTCOME

One hundred and thirty-seven papers were returned using the reported search. From these, 11 papers were selected as representing the best evidence on the topic (Table 1).

Table 1: Summary of best evidence

Author, journal, year country, Study type (level of evidence)	Patient group	Outcomes	Key results	Comments
Slobogean *et al.* (2013), J Am Coll Surg, Canada [2] Meta-analysis (level 1a)	Eleven studies (2 RCTs, 8 retrospective studies, 1 case–control study) Total (*n* = 753) Operative (*n* = 367) Non-operative (*n* = 386) RCT Total (*n* = 77) Operative (*n* = 38) Non-operative (*n* = 39) Retrospective studies Total (*n* = 616) Operative (*n* = 299) Non-operative (*n* = 317) Case–control study Total (*n* = 60) Operative (*n* = 30) Non-operative (*n* = 30) Time period: 1965–2008		Operated vs non-operated OR: 0.31 (0.20–0.48), RD: 0.19 (0.13–0.26), NNT 5 MD 7.5 (95% CI 5.5–9.9) MD 4.8 (95% CI 1.6–7.9) MD 4.0 (95% CI 0.7–7.4) OR 0.18 (0.11–0.32), RD 0.31 (0.21–0.41), NNT 3 OR 0.12 (0.04–0.32), RD 0.34 (0.10–0.57) NNT 3 OR 0.36 (0.19–0.71), RD 0.14 (0.56–0.23), NNT 7 OR 0.40 (0.16–1.01, RD 0.15 (−0.09–0.39) NNT 7 OR 0.40 (0.01–12.60), RD 0.30 (−0.46–0.83) NNT 5 OR 0.11 (0.02–0.60), RD 0.30 (−0.00–0.60) NNT 3	Surgical fixation resulted in reductions in - in-hospital mortality - mechanical ventilation - ICU stay - hospital stay - tracheostomies - pneumonia - septicaemia - dyspnoea - chest pain - chest wall deformities
Marasco *et al.* (2013), J Am Coll Surg, Australia [3] Prospective randomized, controlled study (level 1b)	Patients with traumatic flail chest injury receiving invasive mechanical ventilation were divided in two groups: - Total (*n* = 46) - Operative (*n* = 23) - Non-operative (*n* = 23) Time period: January 2007–December 2011		Operated vs non-operated 0% (0/23) vs 4.3% (1/23); *P* = 0.87 3 (0–25) vs 50 (17–102); *P* = 0.01 285 (191–319) vs 359 (270–581); *P* = 0.03 48% (11/23) vs 74% (17/23), *P* = 0.07 39% (9/23) vs 70% (16/23), *P* = 0.04 930 (620–1860) vs 900 (500–1395) *P* = 0.57 FEV1 *P* = 0.31, FVC *P* = 0.19, MMEF *P* = 0.64, PEF *P* = 0.63, TLC *P* = 0.61, FEV1/FVC *P* = 0.92 - Physical functioning *P* = 0.24 - Physical role *P* = 0.36 - Bodily pain *P* = 0.22 - General health *P* = 0.77 vitality/energy *P* = 0.49 - Social functioning *P* = 0.79 - Emotional role *P* = 0.97 - Mental health *P* = 0.87 - Physical component summary score *P* = 0.65 - Mental component summary score *P* = 0.98	Surgical fixation resulted in reductions in - mechanical ventilation - ICU stay - tracheostomies

Continued

Table 1: (*Continued*)

Author, journal, year country, Study type (level of evidence)	Patient group	Outcomes	Key results	Comments
Jayle *et al.* (2015), Biomed Int, France [4] Prospective randomized, controlled study (level 1b)	Polytraumatized patients with flail chest were randomized to a surgical group and a control group by age ± 10 years, sex, neurological or vertebral trauma, abdominal injury and arm and leg fractures - Total (*n* = 20) - Operative (*n* = 10) - Non-operative (*n* = 10) Time period: April 2011–April 2012	 Ventilator hours ICU days Hospital days	Operated vs non-operated 73.5 ± 124.7 vs 141.6 ± 224.4, *P* = 0.026 9.0 ± 4.3 vs 12.3 ± 8.5, *P* = 0.076 21.7 ± 7.8 vs 32.3 ± 19.3, *P* = 0.024	Surgical fixation resulted in reductions in - mechanical ventilation - hospital days
Pieracci *et al.* (2015), J Trauma Acute Care Surg, USA [5] Prospective randomized, controlled study (level 1b)	Patients with flail chest treated with surgical internal rib fixation were matched to a non-operatively treated group - Total (*n* = 70) - Operative (*n* = 35) - Non-operative (*n* = 35) Time period: Non-operative: January 2013–December 2013 Operative: January 2014–December 2014	 Ventilator days Tracheostomy Respiratory failure Daily spirometry value	Operated vs non-operated 0 (0–8) vs 5.0 (0–18), *P* < 0.01 OR = 0.18 (0.04–0.78), *P* = 0.03 OR = 0.24 (0.06–0.93), *P* = 0.03 250 ml higher in the operative group, *P* = 0.04	Surgical fixation resulted in reductions in - mechanical ventilation - tracheostomies - respiratory failure No mortalities
Zhang *et al.* (2015), Am Emerg J Med, China [6] Retrospective cohort study (level 2b)	Patients with severe flail chest treated with surgical internal rib fixation were matched to a non-operatively treated group - Total (*n* = 39) - Operative (*n* = 24) - Non-operative (*n* = 15) Time period: July 2010–December 2013	 Ventilator days ICU days Hospital days Tracheostomy Mortality	Operated vs non-operated 12 (7.5, 17.75) vs 7 (4, 14), *P* = 0.233 24.5 (21.25, 30.75) vs 21.5 (18, 33.5), *P* = 0.719 38 (33, 54.25) vs, 60 (38, 99.75), *P* = 0.049 50% (12/24) vs 46.7% (7/15), OR 1.143 (0.314–4.160), *P* = 1.000 0% (0/24) vs 13.3% (2/15), *P* = 0.142	Surgical fixation resulted in reductions in hospital days
Wada *et al.* (2015), J Crit Care, Japan [7] Retrospective cohort study (level 2b)	Patients with flail chest treated with surgical internal rib fixation were matched to a non-operatively treated group - Total (*n* = 420) - Operative (*n* = 84) - Non-operative (*n* = 336) Time period: July 2010–March 2013	 Prolonged mechanical ventilation or death within 28 days Tracheostomy or death within 28 days	Operated vs non-operated 22.6 vs 33.3%; OR 0.59; 95% CI 0.36–0.96, *P* = 0.34 OR 0.65 (95% CI 0.35–1.22), *P* = 0.176	Surgical fixation resulted in reductions in 28-days mechanical ventilation or mortality
Granhed *et al.* (2014), J Trauma Manag Outcomes, Sweden [8] Retrospective cohort study (level 2b)	Patients who underwent surgical rib fixation for acute flail chest were matched to a historical group who received conservative treatment - Total (*n* = 213) - Operative (*n* = 60) - Non-operative (*n* = 153)	 Ventilator days Pneumonia Costs (US Dollar)	Operated vs non-operated 2.7 vs 9.1, *P* < 0.007 0% (0/60) vs 0% (0/152) 32 300 vs 37 100	Surgical fixation resulted in reductions in mechanical ventilation Lower but not significant reduction of costs in the surgical group

Continued

Table 1: (*Continued*)

Author, journal, year country, Study type (level of evidence)	Patient group	Outcomes	Key results	Comments
	Time period: Operative: September 2010–July 2012 Non-operative: January 2005–December 2010			No fracture dislocations or complications in the surgical group
Doben *et al.* (2014), J Crit Care, USA [9] Retrospective cohort study (level 2b)	Patients who underwent surgical rib fixation for acute flail chest were matched to a historical group who received conservative treatment - Total (n = 21) - Operative (n = 10) - Non-operative (n = 11) Time period: Operative: September 2010–June 2010 Non-operative: historical group	Ventilator days ICU days Hospital days	Operated vs non-operated 4.5 (0–30) vs 16 (4–40), P = 0.04 9 (5–31) vs 18 (5–22), P = 0.370 13 (8–59) vs 22 (6–50), P = 0.169	Surgical fixation resulted in reductions in mechanical ventilation
Xu *et al.* (2015), Eur J Med Res, China [10] Retrospective cohort study (level 2b)	Patients with severe flail chest treated with surgical internal rib fixation and conservatively treated patients were compared - Total (n = 32) - Operative (n = 17) - Non-operative (n = 15) Time period: July 2007–July 2012	Ventilator days ICU days Pneumonia Tracheostomy Reintubation APACHE II score Day 7 after trauma Day 14 after trauma	Operated vs non-operated 10.5 ± 3.7 vs 13.7 ± 4.4, P = 0.03 15.9 ± 5.0 vs 19.6 ± 5.0, P = 0.05 58.8% (9/15) vs 93.3% (16/17), P = 0.02 40% (6/15) vs 12% (2/17), P = 0.066 20% (3/15) vs 6% (1/17), P = 0.288 13.4 ± 5.8 vs 11.4 ± 5.0, P = 0.350 6.5 ± 3.8 vs 10.1 ± 4.7, P = 0.02	Surgical fixation resulted in reductions in - mechanical ventilation - ICU stay - Pneumonia - APACHE II score 14 days after trauma 1 death of ARDS in the conservative group No wound infections/ broken/loose metal plates in the surgical group
Althausen *et al.* (2011), J Orthop Trauma, USA [11] Retrospective case–control study (level 3)	Patients with severe flail chest treated with surgical internal rib fixation were compared with non-operatively managed patients - Total (n = 50) - Operative (n = 22) - Non-operative (n = 28) Time period: January 2005–January 2010	Ventilator days ICU days Hospital days Pneumonia Tracheostomy Reintubation Home oxygen requirements	Operated vs non-operated 4.14 vs 9.68, P = 0.007 7.59 vs 9.68, P = 0.018 11.9 vs 19.0, P = 0.06 4.55% (1/22) vs 25% (7/28), P = 0.047 4.55% (1/22) vs 39.29% (11/28), P = 0.042 4.55% (1/22) vs 17.86% (5/28), P = 0.034 4.55% (1/22) vs 17.86% (5/28), P = 0.034	Surgical fixation resulted in reductions in - mechanical ventilation - ICU stay - hospital stay - pneumonia - tracheostomy - reintubation - home oxygen requirements. No case of hardware failure, plate prominence, wound infection or non-union was reported
De Moya *et al.* (2011), J Trauma Acute Med, USA [12]	Patients with severe flail chest treated with surgical internal rib fixation were matched to a non-operatively treated group	Ventilator days	Operated vs non-operated 7 ± 8 vs 6 ± 10, P = 0.44	No differences in outcomes were observed between the surgical and non-surgical group

Continued

Table 1: (*Continued*)

Author, journal, year country, Study type (level of evidence)	Patient group	Outcomes	Key results	Comments
Retrospective case–control study (level 3)	- Total (n = 48) - Operative (n = 16) - Non-operative (n = 32) Time period: July 2005–June 2009	ICU days	9 ± 8 vs 7 ± 10, P = 0.75	The need for morphine was significantly reduced in the surgical group after rib fixation
		Pneumonia	31% (5/16) vs 38% (12/32), P = 0.76	
		Hospital days	18 ± 12 vs 16 ± 11, P = 0.67	
		Mean morphine requirements (mg)	79 ± 63 vs 76 ± 55 mg, P = 0.65	
		Surgical group: Morphine requirements (mg)	Preoperative vs postoperative 110 ± 98 vs 63 ± 57, P = 0.01	

ARDS: acute respiratory distress syndrome; TLC: total lung capacity; PEF: peak expiratory flow; MMEF: maximum mid expiratory flow; FVC: forced vital capacity; CT: computed tomography; MD: mean decrease (95% CI); OR: odds ratio (95% CI); RD: risk difference (95% CI); NNT: number needed to treat; PE: pooled estimates; RCT: randomized, controlled trials.

RESULTS

Slobogean *et al.* [2] included 11 studies with a total of 753 patients in a meta-analysis (2 randomized controlled trials, 8 retrospective studies, 1 case–control study). Methods of fixation varied from using K-wires, steel wires, Adkin and Judet struts, titanium plates and the osteosynthesis rib fixation system. Funnel plot analysis demonstrated no potential bias for the pooled outcomes. Surgical fixation resulted in better outcomes for all pooled analyses, including decreases in ventilator days (mean 8 days) and the odds of developing pneumonia [odds ratio (OR) 0.2]. There were decreases in intensive care unit (ICU) days (mean 5 days), mortality (OR 0.31), septicaemia (OR 0.36), tracheostomy (OR 0.06), dyspnoea (OR 0.4) and chest deformity (OR 0.11).

Marasco *et al.* [3] randomized 46 polytrauma patients with an acute flail chest who were ventilated to an operative (n = 23) and a non-operative (n = 23) group. The operative group had a significantly shorter ICU stay than the non-operative group (285 vs 359 h, P = 0.03). The need for non-invasive ventilation after extubation was shorter in the operative group (3 vs 50 h, P = 0.01). No differences were found for the in-hospital mortality (P = 0.87), blood transfusion requirements (P = 0.57), incidence of pneumonia (P = 0.07), spirometry at 3 months (P = 0.92) and quality of life at 6 months (P = 0.98).

Jayle *et al.* [4] prospectively divided 20 polytraumatized patients with flail chest into a surgical group (n = 10) and a control group (n = 10). There were no significant differences between groups for matched data and prognostic scores including: injury severity score (ISS), revised trauma score, trauma ISS and ICU stay (9.0 ± 4.3 vs 12.3 ± 8.5 days, P = 0.076). Surgical fixation resulted in a significant decrease in the duration of mechanical ventilation (73.5 ± 124.7 vs 142.6 ± 224.4 days, P = 0.026) and in the length of hospital stay (21.7 ± 7.8 vs 32.3 ± 19.3 days, P = 0.024).

Pieracci *et al.* [5] prospectively randomized 70 patients with flail chest into a surgically (n = 35) and a non-surgically (n = 35) managed group. A significant reduction was shown in the duration of mechanical ventilation (0 vs 5 days, P < 0.01), for tracheostomy (OR = 0.18, P = 0.03) and the risk for respiratory failure (OR = 0.24, P = 0.03). The spirometry value was 250 ml greater in the surgical group (P = 0.04).

Zhang *et al.* [6] included 39 patients with flail chest and divided them into a surgical (n = 24) and a non-surgical (n = 15) group. The surgical group demonstrated a significant reduction in the length of hospital stay (38 vs 60 days, P = 0.049). No differences were observed in the duration of ventilator days (12 vs 7 days, P = 0.233), the rate of tracheostomies [50% (12/24) vs 46.7% (7/15), OR 1.14, P = 1.000], length of ICU stay (24.5 vs 21.5 days, P = 0.719) or mortality [0% (0/24) vs 13.3% (2/15), P = 0.142] between the two groups.

Wada *et al.* [7] retrospectively matched 84 surgically treated patients with flail chest to a conservatively managed group (n = 336). The surgical group was significantly less likely to experience the combined end-point of prolonged mechanical ventilation or death within 28 days (22.6 vs 33.3%; OR 0.59, P = 0.034).

Granhed *et al.* [8] retrospectively matched consecutive patients who underwent surgical rib fixation for acute flail chest (n = 60) to a historical control group (n = 153) who had received conservative treatment. Surgical fixation resulted in significant reductions in the duration of mechanical ventilation (9.1 vs 2.7 days, P < 0.001) as well as a tendency towards lower costs ($32,300 vs $37,100). No differences were found in the ISS or for chest infections between the two groups.

Doben *et al.* [9] retrospectively divided 21 patients with flail chest into a surgical group (n = 10) treated with rib fixation and a non-surgical group (n = 11). The surgical group demonstrated a significant reduction in total ventilator days compared with the non-surgical group (4.5 vs 16.0 days, P = 0.04).

Xu *et al.* [10] retrospectively divided 32 patients with severe flail chest into a surgically (n = 17) and a conservatively managed group (n = 15). The surgical group demonstrated a significant reduction in the duration of mechanical ventilation (10.5 ± 3.7 vs 13.7 ± 4.4 days, P = 0.03), the length of ICU stay (15.9 ± 5.0 vs

19.6 ± 5.0 days, $P = 0.05$), lower risks for the development of pneumonia (58.8 vs 93.3%, $P = 0.02$) and a better APACHE II score 14 days after trauma (6.5 ± 3.8 vs 10.1 ± 4.7, $P = 0.02$). No differences were observed in the APACHE II score 7 days after trauma ($P = 0.350$), the rate of tracheostomies ($P = 0.066$) and the rate of endotracheal reintubation ($P = 0.288$) between the two groups. There were no wound infections or broken/loose metal plates in the surgical group.

Althausen *et al.* [11] compared operatively managed patients ($n = 22$) with severe flail chest with a non-operatively managed group ($n = 28$). The group treated with internal rib fixation demonstrated a significant reduction in the duration of mechanical ventilation (4.14 vs 9.68 days, $P = 0.007$), length of ICU stay (7.59 vs 9.68 days, $P = 0.018$), length of hospital stay (11.9 vs 19.0 days, $P = 0.06$) and incidence of pneumonia. Furthermore, surgical management resulted in a reduction of tracheostomies (13.64 vs 39.29%, $P = 0.042$), reintubations (4.55 vs 17.86%, $P = 0.034$) and reduced requirements for home oxygen (4.55 vs 17.86%, $P = 0.034$). There were no cases of fixation failure, plate prominence, wound infection or non-union.

De Moya *et al.* [12] matched a surgically treated group with severe flail chest ($n = 16$) to a conservatively treated group ($n = 32$). No differences in outcomes were observed between the surgical and non-surgical group for ventilator days, the length of ICU stay ($P = 0.75$), the incidence of pneumonia ($P = 0.76$), the length of hospital stay ($P = 0.67$) or the mean morphine requirements ($P = 0.65$). Morphine usage in the surgical group was significantly reduced postoperatively (preoperative 110 ± 98 vs 63 ± 57 mg postoperatively, $P = 0.01$).

One meta-analysis [13] was excluded from the results due to the overlap in data to the meta-analysis by Slobogean *et al.* [2]. All the papers that did not overlap were independently included in this review.

CLINICAL BOTTOM LINE

Surgical stabilization of flail chest in thoracic trauma patients has beneficial effects with respect to reduced ventilatory support, shorter intensive care and hospital stay, reduced incidence of pneumonia and septicaemia, decreased risk of chest deformity and an overall reduced mortality when compared with patients who received non-operative management.

Conflict of interest: none declared.

REFERENCES

[1] Dunning J, Prendergast B, Mackway-Jones K. Towards evidence-based medicine in cardiothoracic surgery: best BETS. Interact CardioVasc Thorac Surg 2003;2:405–9.

[2] Slobogean GP, MacPherson CA, Sun T, Pelletier ME, Hameed SM. Surgical fixation vs nonoperative management of flail chest: a meta-analysis. J Am Coll Surg 2013;216:302–11.e1.

[3] Marasco SF, Davie AR, Cooper J, Varma D, Bennett V, Nevill R *et al.* Prospective randomized controlled trial of operative rib fixation in traumatic flail chest. J Am Coll Surg 2013;216:924–32.

[4] Jayle CPM, Allain G, Ingrand P, Lasiri L, Bonnin E, Hajj-Chahine J *et al.* Flail chest in polytraumatized patients: surgical fixation using Stracos reduces ventilator time and hospital stay. BioMed Res Int 2015; 2015:1–6.

[5] Pieracci FM, Lin Y, Rodil M, Synder M, Herbert B, Tran DK *et al.* A prospective, controlled clinical evaluation of surgical stabilization of severe rib fractures. J Trauma Acute Care Surg 2016;80:187–94.

[6] Zhang Y, Tang X, Xie H, Wang RL. Comparison of surgical fixation and non-surgical management of flail chest and pulmonary contusion. Am J Emerg Med 2015;33:937–40.

[7] Wada T, Yasunaga H, Inokuchi R, Matsui H, Matsubara T, Ueda Y *et al.* Effectiveness of surgical rib fixation on prolonged mechanical ventilation in patients with traumatic rib fractures: a propensity score-matched analysis. J Crit Care 2015;30:1227–31.

[8] Granhed HP, Pazooki D. A feasibility study of 60 consecutive patients operated for unstable thoracic cage. J Trauma Manag Outcomes 2014; 8:20.

[9] Doben AR, Eriksson EA, Denlinger CE, Leon SM, Couillard DJ, Fakhry SM *et al.* Surgical rib fixation for flail chest deformity improves liberation from mechanical ventilation. J Crit Care 2014;29:139–43.

[10] Xu JQ, Qiu PL, Yu RG, Gong SR, Ye Y. Better short-term efficacy of treating severe flail chest with internal fixation surgery compared with conservative. Eur J Med Res 2015;20:55.

[11] Althausen PL, Shannon S, Watts C, Thomas K, Bain MA, Coll D *et al.* Early surgical stabilization of flail chest with locked plate fixation. J Orthop Trauma 2011; 25:641–7.

[12] De Moya M, Bramos T, Agarwal S, Fikry K, Janjua S, King DR *et al.* Pain as an indication for rib fixation: a bi-institutional pilot study. J Trauma 2011;71:1750–4.

[13] Leinicke JA, Elmore L, Freeman BD, Colditz GA. Operative management of rib fractures in the setting of flail chest: a systematic review and meta-analysis. Ann Surg 2013;258:914–21.

eComment. Further series

Author: ***John G. Edwards***
Sheffield Teaching Hospitals NHS Foundation Trust, Sheffield, UK

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The Best Evidence Topic presented by Schulte *et al.* is welcomed. However, it should be noted that both the series published by Jayle *et al.* and that by Pieracci *et al.* were sequential cross-over cohort series. There is no comment in the manuscript by Jayle *et al.* as to whether the study was propsective: it can only be interpreted as a retrospective case-control study. Pieracci's *et al.* was not a prospective randomized trial, but they do describe it as a prospective controlled trial.

There is an additional published study which may be of value, although interpretation is difficult [2].

Furthermore, there are a number of prospective randomized trials underway at the current time, as registered at www.clinicaltrials.gov.

Finally, the clinical scenario presented suggested that the patient had pulmonary contusions. Whether to fix or not in this setting is an interesting debate in itself!

Conflict of interest: none declared.

References

[1] Schulte K, Whitaker D, Attia R. In patients with acute flail chest does surgical rib fixation improve outcomes in terms of morbidity and mortality? Interact CardioVasc Thorac Surg 2016;23:314–20.

[2] Wu WM, Yang Y, Gao ZL, Zhao TC, He WW. Which is better to multiple rib fractures, surgical treatment or conservative treatment? Int J Clin Exp Med 2015;8:7930–7936.

eReply: In patients with acute flail chest does surgical rib fixation improve outcomes in terms of morbidity and mortality?

Authors: ***Rizwan Q. Attia, Katharina L. Schulte and Donald C. Whitaker***
Department of Cardiothoracic Surgery, King's College Hospital, London SE5 9RS, UK

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We welcome and agree with the comments by John Edwards [1] on the evidence for rib fixation for acute flail chest [2]. The series published by Jayle *et al.* [3] is described by the authors as 'a matched case-control study that prospectively included patients with multiple trauma and blunt chest injury' that were treated over