Operative Treatment of Rib Fractures in Flail Chest Injuries: A Meta-Analysis and Cost-Effectiveness Analysis

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Background/Purpose: Flail chest is a common injury sustained by patients who suffer from high-energy blunt chest trauma, and results in severe respiratory compromise due to altered mechanics or respiration with paradoxical chest wall motion. Historically treatment has been supportive, with patients treated with pain control and respiratory assistance, usually in the form of mechanical ventilation. However, there has been increased interest in operative fixation of these injuries with the intention of restoring the mechanical integrity of the chest wall and several studies have shown that ventilation requirements and pulmonary complications may be decreased with operative intervention. The purpose of this study was to conduct a cost-effectiveness analysis, supported by systematic review and meta-analysis, to evaluate if the respiratory benefits and decreased ventilator support after fixation is enough to justify the additional cost requirements of operative fixation and perioperative complications.

Methods: This was a two-part study in which we initially conducted a systematic review and meta-analysis of the current literature evaluating outcomes after operative fixation of flail chest injuries. Major outcome measures investigated included ICU stay/ventilator requirements, total hospital length of stay, perioperative complications, pneumonia, tracheostomy, and mortality. The results from that analysis were then applied to a decision-analysis model comparing the costs and outcomes of operative fixation versus nonoperative treatment of flail chest injuries. Clinical outcome measures were determined from our meta-analysis, and health utility states and costs were derived from existing literature and Medicare costs. The validity of the results were tested using multiway sensitivity analysis within literature-reported ranges.

Results: Operative treatment decreased mortality, pneumonia, and tracheotomy (risk ratios of 0.41, 0.45, and 0.37 respectively), as well as time in ICU and total length of stay (3.2 and 2.9 days, respectively). For the base case in the economic model (a polytrauma patient suffering a flail chest injury), operative fixation was the dominant strategy (decreased total cost and increased quality of life), decreasing total cost by $801 and improving quality-adjusted life years by 5.82 per case. These results were maintained for all ranges tested in sensitivity analysis, as long as overall surgical complication rate stayed below 27%.

Conclusion: Surgical fixation of rib fractures sustained from flail chest injuries decreases ICU time, mortality, pulmonary complications, and hospital length of stay, and results in improved health care-related outcomes at a net decreased cost. These results are sensitive to overall complication rates, and operations should be conducted by surgeons or combined surgical teams comfortable with both thoracic anatomy and exposures as well as with the principles and techniques of internal fixation.

See pages 49 - 106 for financial disclosure information.

Table 1 – Results of Literature Review and Meta-Analysis

		Number of patients		Ventilator Time [days]				ICU LOS [days]				Hospital LOS [days]				Mortality		Pneumonia		Tracheostomy	
		ORIF	Non-Op	ORIF		Non-Op		ORIF		Non-Op		ORIF		Non-Op		Op	Non-Op	Op	Non-Op	Op	Non-Op
Study	LoE			Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Inc	Inc	Inc	Inc	Inc	Inc
Ahmed et al.[29]	3	26	38	3.9	*4.3*	15.0	*6.4*	9.0	*3.9*	21.0	*5.3*					0.08	0.29	0.15	0.50	0.12	0.37
Althausen et al[30].	3	22	28	4.1	*4.7*	9.7	*7.4*	7.3	*4.2*	9.7	*6.1*	11.9	*6.5*	19.0	*8.8*			0.05	0.25	0.14	0.39
Balci et al.[31]	3	27	37	3.1	*1.8*	7.2	*5.8*					18.3	*7.6*	19.3	*6.9*	0.11	0.27			0.00	0.19
de Moya et al.[32]	3	16	32	7.0	*8.0*	6.0	*10.0*	9.0	*8.0*	7.0	*10.0*	18.0	*12.0*	16.0	*11.0*			0.31	0.38		
Doben et al.[13]	3	10	11	8.2	*6.9*	18.0	*11.9*	12.5	*6.2*	15.3	*9.8*	21.6	*9.6*	28.5	*14.1*	0.00					
Granetzny et al.[28]	1	20	20	2.0	*4.9*	12.0	*8.8*	9.6	*4.4*	14.6	*7.3*	11.7	*6.8*	23.1	*10.4*	0.10	0.15	0.10	0.50		
Granhed et al.gran[10]	3	60	153	2.7	*2.8*	9.0	*3.2*									0.03		0.00			
Jayle et al.[9]	3	10	10	3.1	*5.2*	5.9	*9.4*	9.0	*4.3*	12.3	*8.5*	21.7	*7.8*	32.3	*19.3*			0.40	0.30		
Karev et al.[33]	3	40	93	2.3	*0.6*	6.3	*1.2*									0.23	0.46	0.15	0.34		
Kim et al.[34]	3	18	45													0.06	0.22				
Marasco et al.[11]	1	23	23	6.3	*3.5*	7.5	*5.4*	13.5	*3.0*	18.7	*4.1*					0.00	0.04	0.48	0.74	0.39	0.70
Nirula et al.[35]	3	30	30	6.5	*1.3*	11.2	*2.6*	12.1	*1.2*	14.1	*2.7*	18.8	*1.8*	21.1	*3.9*						
Tanaka et al.[36]	1	18	19	10.8	*3.4*	18.3	*7.4*	16.5	*7.4*	26.8	*13.2*							0.22	0.89	0.28	0.79
Teng et al.[37]	3	32	28	14.0	*3.9*	20.0	*7.4*	8.7	*3.5*	15.2	*6.1*	17.1	*5.4*	22.4	*8.8*			0.13	0.43		
Voggenreiter et al.[38]	3	20	22	18.8	*20.3*	27.2	*27.8*									0.15	0.36	0.25		0.32	
Xu et al.[39]	3	17	15	10.5	*3.7*	13.7	*4.4*	15.9	*5.0*	19.6	*5.0*					0.00	0.07	0.59	0.93	0.12	0.40
Heterogeneity (I^2)				81%				63%				44%				0%		40%		0%	
Meta-analysis effect size (SD)				5.26 days (± 0.92 days)				3.81 days (± 0.82 days)				2.88 days (± 0.61days)				RR 0.41 (± 0.09)		RR 0.45 (± 0.06)		RR 0.37 (± 0.08)	
Effect size using only level 1 studies				6.03 days (± 2.74 days)				6.84 days (± 2.48 days)				3.01 days (± 0.73 days)				RR 0.56 (± 0.57)		RR 0.39 (± 0.09)		RR 0.46 (± 0.11)	

ORIF = open reduction internal fixation. Non-Op = patients treated non-operatively with standard of care. LoE = Level of Evidence. Avg = Average value. SD = Standard Deviation. Inc = Incidence rate. RR = risk ratio