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Predictors of Morbidity and Mortality Among Thoracic Trauma Patients

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PREDICTORS OF MORBIDITY AND MORTALITY AMONG THORACIC TRAUMA PATIENTS

by

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Predictors of Morbidity and Mortality Among Thoracic Trauma Patients

Abstract

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Background. There are roughly 300,000 rib fractures treated for in the United States each year. These represent 10-26% of thoracic trauma injuries and have about a 10% mortality rate. There is a common belief that mortality in rib fracture patients can be contributed to the diagnosis of pneumonia, but this study does not support that claim. Purpose. To determine the predictors of morbidity and mortality in rib fracture patients. Methods. Using a level 1 trauma center patient registry, we retrospectively analyzed all patients that were admitted with at least one rib fracture (n=1,344). All predictors were analyzed with linear regressions. Results. The average age of the patients was 55.48 ± 20.29 years old and ranged between 15 and 98. ISS (OR: 1.0508, $p<0.001$), bilateral fractures (OR: 1.9495, $p = 0.009$) and pulmonary contusion (OR: 1.7481, $p = 0.022$) were all significant predictors of pneumonia. The age of the patient (OR: 1.0467, $p < 0.001$), ISS (OR: 1.0585, $p <0.001$), having 6 or more fractured ribs (OR: 3.1450, $p < 0.001$), the presence of hemothorax (OR: 2.5063, $p = 0.048$), and the use of mechanical ventilation (OR: 13.2125, $p < 0.001$) were all significant predictors of mortality. Flail segments (OR: 1.9871, $p = 0.067$), ISS (OR: 1.1267, $p < 0.001$), pulmonary contusions (OR: 1.5329, $p = 0.047$), pneumothorax (OR: 1.4372, $p =0.073$) and pneumonia (OR: 21.4516, $p < 0.001$) are all predictors of requiring mechanical ventilation. Conclusion. There are many studies that indicate rib fracture patients who are diagnosed with pneumonia have a higher risk or mortality. With

this in mind, the logical course of treatment would be to counteract the complications pneumonia brings as to reduce the risk or mortality. To do this, it is recommend the patient be put on mechanical ventilation. While this has been seen to help with pneumonia patients, this study provides evidence that health care professionals should look for ways to reduce the need for mechanical ventilation instead of using it to combat the pneumonia.

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Chapter 1: Introduction

Thoracic trauma is one of the leading causes of injury related deaths in the United States, only surpassed by head injuries (Flagel et al., 2005). Of the thoracic injuries seen each year, 10-26% of the cases seen are rib fractures. (Dehghan, de Mestral, McKee, Schemitsc, & Nathens, 2014; Flagel et al., 2005; Sharma et al., 2008; Shulzhenko et al., 2017; Todd et al., 2006) On average, hospitals across the United States see between 150,000 and 300,000 rib fracture cases every year (Jensen et al., 2016). Although detection of rib fractures may seem diagnostically simple, there are still numerous cases missed in trauma settings, increasing the number of patients annually admitted with this injury(Cameron, Dziukas, Hadj, Clark, & Hooper, 1996). While this may be perceived as a relatively minor injury, the consequences are often severe. The average rate of mortality is about 10% (Flagel et al., 2005; Jensen et al., 2016; Sharma et al., 2008) and this can potentially double in patients over the age of 65 (Bulger, Arneson, Mock, & Jurkovich, 2000). In addition to age, mortality is also affected by the number of ribs fractured (Todd et al., 2006). Typically, a greater number of fractured ribs exacerbates the pain experienced with breathing. As a consequence, this can lead to impaired lung function, and in turn, the development of diseases such as pneumonia, empyema, and respiratory distress syndrome (Yeh, Kutcher, Knudson, & Tang, 2012).

In addition to the high risk of mortality, rib fractures are an expensive injury. Although data are limited, and depend on variables such as presentation of injury , treatment type, and the length of stay, the mean patient bill at our institution was \$89,209 ± \$123,094 (range = \$2,448 to \$1,487,194) (Jensen et al., 2017). This equates to \$12,099 ± \$9,116 per day of treatment. The average expense for the hospital to deliver this care was \$13,611 ± \$43,807 (range = \$61–\$985,080) (Jensen et al., 2017).

A more comprehensive understanding of the patient population at admission can lead to better treatment decisions, ideally reducing the cost of care while improving patient outcomes. Thus, it is important to know the typical patient profile and the likelihood of morbidity and mortality based on the individual patient characteristics and presentation of injury. Knowing this will help medical professionals more efficiently diagnose and treat rib fractures. In addition to minimizing adverse effects, this will also improve patient satisfaction. Making them feel like they are more than just another case and that they got everything they needed will increase revenue in the long run. In a health care setting the money comes from the patients that are seen. As seen in many workplaces, in order to increase the profit there needs to be an increase in the number of patients. The best way to do this is through having high patient satisfaction because that will not only make them want to come back, but they will also more likely refer other patients (Lahiff, 2012).

Chapter 2: Review of the Literature

A review of rib fracture studies was performed to find the demographics, injury characteristics, and typical outcomes of rib fracture patients. A total of 125 articles were examined from the 1970s to the 2017. Three articles were from the 1970s, seven were from the 1980s, 14 from the 1990s, 45 from the early 2000s (2000-2009) and 56 were from 2010 to 2017. Variables recorded from these articles included age, sex, numbers of rib fractured, incidence of a flail chest, incidence of a pulmonary contusion, mean injury severity score (ISS), hospital length of stay, ICU length of stay, incidence of pneumonia, number of patients that underwent mechanical ventilation, and mortality. Table 1 shows the percentage of articles that reported each variable and is broken down by decade. All of the articles reported the age of their populations. 82.4% of them included the average age. 86.4% of them had the number of men and women in the study. 47.2% of them reported the average number of ribs fractured. Flail segments were tracked in 39.2% of the studies. The number of pulmonary contusions were reported by 36.8% of the articles. 48.8% of them had the injury severity score. The hospital and ICU length of stay was seen in 49.6% and 35.2% of the studies respectively. 34.4% of them had the number of pneumonia cases. Mechanical ventilation was in 23.2% of the articles. Mortality was reported in 41.6% of the studies examined.

Table 1: Descriptive variables given per decade

		N	Mean	Std. Deviation
Age years	1970s	3	45.0	5.7
	1980s	7	43.7	8.3
	1990s	11	49.8	11.4
	2000s	38	48.2	14.9
	2010-18	44	53.3	11.5
	Total	103	50.2	12.8
Mean ISS	1970s	0	.	.
	1980s	3	22.7	9.1
	1990s	7	17.3	3.3
	2000s	22	20.1	6.7
	2010-18	29	19.7	7.5
	Total	61	19.7	6.8
Mean number ribs fractured	1970s	3	5.7	1.0
	1980s	4	5.6	0.9
	1990s	4	5.5	1.0
	2000s	17	4.1	1.8
	2010-18	31	5.9	2.4
	Total	59	5.3	2.2
Percent with flail segment	1970s	1	100.0%	.
	1980s	3	51.0%	43.68%
	1990s	1	50.0%	.
	2000s	18	25.5%	30.80%
	2010-18	25	47.3%	41.61%
	Total	48	40.5%	38.77%
Percent with pulmonary contusion	1970s	1	11.0%	.
	1980s	2	31.4%	30.3%
	1990s	5	36.0%	17.4%
	2000s	20	33.7%	19.6%
	2010-18	18	52.6%	29.9%
	Total	46	40.8%	25.5%
Percent of cases of pneumonia	1970s	1	58.6%	.
	1980s	3	27.1%	8.9%
	1990s	4	14.0%	12.6%
	2000s	17	15.8%	12.8%
	2010-18	17	17.1%	15.6%
	Total	42	18.0%	15.0%

Percent of patients receiving mech ventilation	1970s	2	74.8%	1.5%
	1980s	4	44.5%	16.0%
	1990s	2	60.8%	18.3%
	2000s	10	46.8%	30.2%
	2010-18	11	18.9%	14.5%
	Total	29	38.8%	26.8%
Hospital LOS	1970s	1	34.1	.
	1980s	4	16.4	10.8
	1990s	6	12.6	3.0
	2000s	22	11.2	6.3
	2010-18	29	13.2	7.0
	Total	62	13.0	7.2
ICU LOS	1970s	1	52.2	.
	1980s	1	2.3	.
	1990s	4	5.5	2.8
	2000s	15	6.8	6.0
	2010-18	23	7.0	4.4
	Total	44	7.7	8.4
Percent of mortalities	1970s	3	10.4%	6.4%
	1980s	4	10.2%	10.6%
	1990s	4	9.4%	4.5%
	2000s	21	7.1%	5.0%
	2010-18	19	10.4%	22.0%
	Total	51	9.0%	14.0%

Demographics and Injury Characteristics of Rib Fracture Patients

Sex. The majority of patients admitted to trauma centers for rib fractures are male (Bulger et al., 2000; Bulger, Edwards, Klotz, & Jurkovich, 2004; Dehghan et al., 2014; Dittmann, Ferstl, & Wolff, 1975; Elmistekawy & AAM, 2007; Govindarajan, Bakalova, Michael, & Abadir, 2002; Griffith et al., 1999; Hashemzadeh, Hashemzadeh, Hosseinzadeh, Maleki, & Golzari, 2011; Reißig & Kroegel, 2005). Two of the three studies in the 1970s provided how many men and women they had in their studies and the average was 78.65% male. In the 1980s five studies gave this information and the average was 72.62% male. The ten studies that had these data in the 1990s had an average of 58.91% male subjects. In the 2000s, the average percent of patients that were men was 64.25% and this was calculated across 38 of 45 studies. There were 53 studies out of 56 in the 2010s that provided how many men were in their studies and the average was 69.97% male. Although some studies have reported more females (Kieninger, Bair, Bendick, & Howells, 2005; Wisner, 1990), the overall percentage was 67.2% male. (Lee, Bass, Morris, & MacKenzie, 1990; Menditto et al., 2012; Reißig & Kroegel, 2005; Trinkle et al., 1975; Waqar, Nasir, & Zahid, 2013).

Age. Rib fractures affect people across the lifespan, including infants as young as 19 days (CADZOW & ARMSTRONG, 2000) and elderly patients as old as 110 years (Shulzhenko et al., 2017) . In the 1970s, the average age was given in all the studies and was 44.97 ± 5.72 years old. All of the studies in the 1980s also reported the average age and between all of them it was 43.66 ± 8.27 years old. There were only three studies that did not report the average age of their patients in the 1990s and the average for this decade was 49.84 ± 11.40 years old. In the 2000s, 38 out of the 45 studies examined reported the average age and in total the average was 48.22 ± 14.92 years old. In the 2010s, 44 out of 56 studies provided the average age and together it came to be 53.29 ± 11.54 years old. The average age increased as the years advanced and can be seen in figure 1. The average age of rib fracture patients in the 103 studies reviewed was 50.16 ± 12.79 years old with an average range of 40-55 years old (Hakim & Latif, 2012; Jensen et al., 2016; Johnston & McCaughey, 1980; Kim et al., 2011).

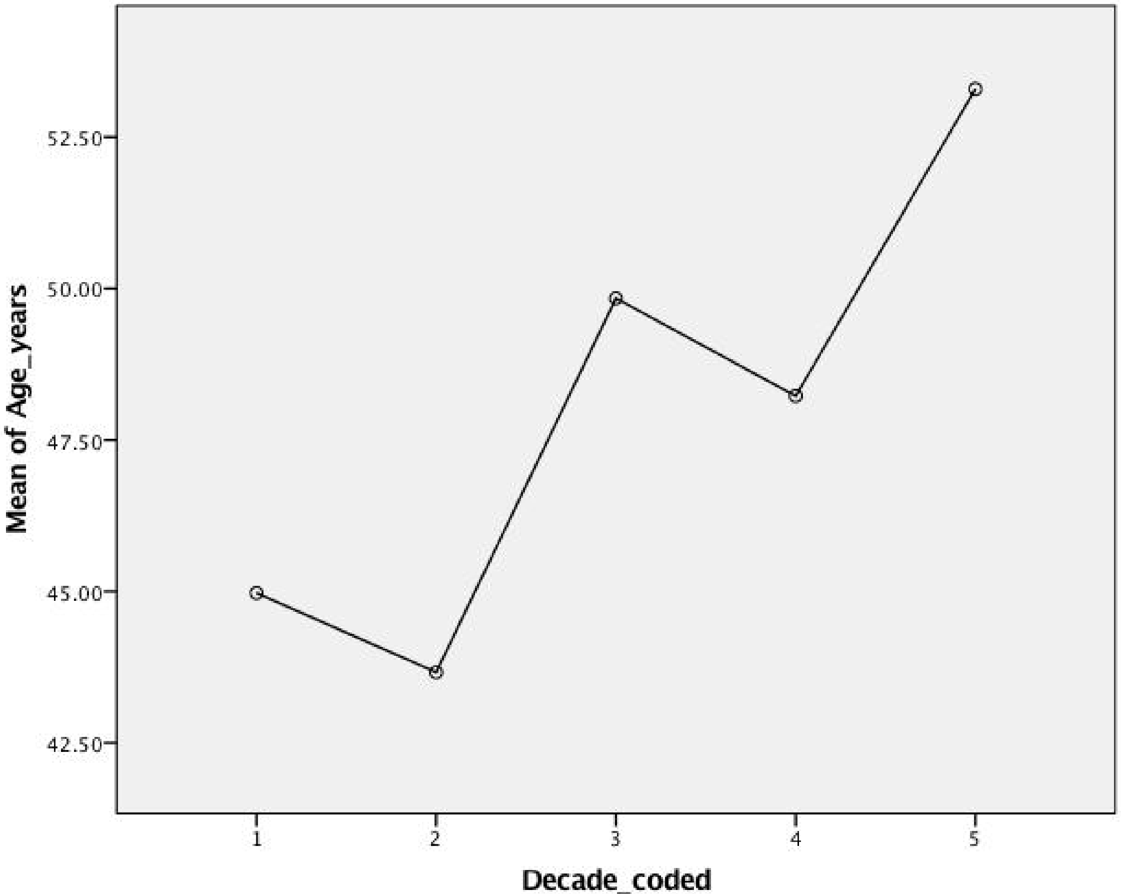

Figure 1: Mean plot of ages across the 1970s, 1980s, 1990s, 2000s and 2010-18.

Average number of ribs fractured. The average range for the number of ribs fractured was between three and six ribs (Govindarajan et al., 2002; Hakim & Latif, 2012; Johnston & McCaughey, 1980; Shinohara, Iwama, Akama, & Tase, 1994). In the 1970s, all of the studies reported the average number of ribs fractured and the overall average was 5.73 ± 0.98 ribs. Four out of the seven studies in the 1980s had these averages and overall it was 5.59 ± 0.93 ribs. Only four of the fourteen studies in the 1990s had the average number of ribs fractured and the average here was 5.53 ± 1.04 ribs. In the 2000s, 14 out of 45 studies reported this information and the average was 4.10 ± 1.78 ribs. In the 2010s, the average was 5.91 ± 2.44 ribs and this was reported in 31 of 56 studies. There was a relatively low average in the 2000s, but it was a consistent number across the other four decades. This trend can be seen in figure 2. The average total number of ribs fractured across all 59 examined studies that reported it was 5.33 ± 2.17 ribs.

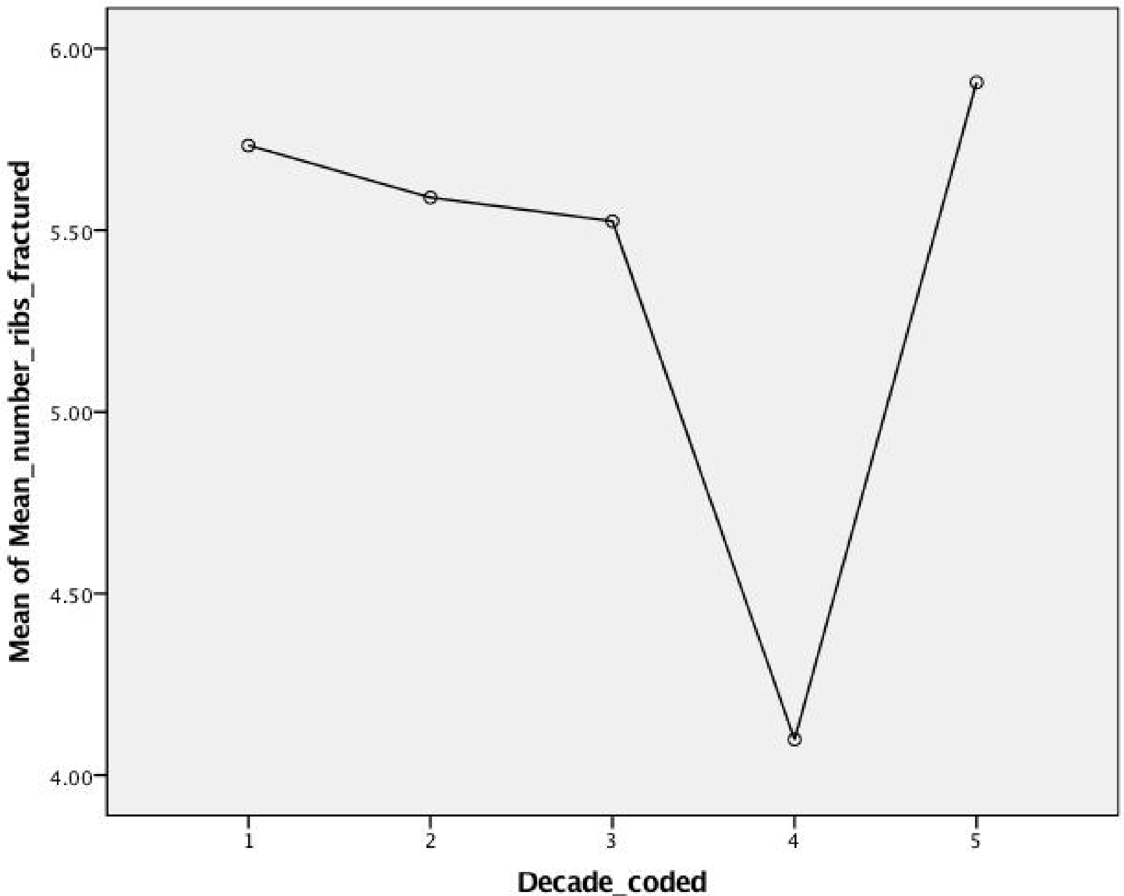

Figure 2: Mean plot of number of ribs fractured across the 1970s, 1980s, 1990s, 2000s and 2010-18.

Injury severity score (ISS). ISS is a common scale used to evaluate trauma severity. It takes into account all of the injured body regions involved to come up with one ISS score. The regions accounted for by this scale include head or neck, face, chest, abdomen, extremities, and external. The scale ranges from 1 (minor injuries) to 75 (unsurvivable injuries). The ISS was not reported in any of the three studies in the 1970s. Three of the 7 studies in the 1980s did have an average ISS and the total average was 22.72 ± 9.13. The average ISS in the 1990s was found in half of the studies and overall it was 17.33 ± 3.32. In the 2000s the average ISS was reported in 22 out of 45 studies and the overall average was 20.10 ± 6.65. The average ISS was given in 29 out of 56 studies in the 2010 decade and the average was 19.65 ± 7.47. ISS seem to be consistent amongst all the decades except in the 1990s where it drops significantly. This can be seen in figure 3. The most common range for ISS across all studies was 14-22 (McKendy et al., 2017; Shulzhenko et al., 2017; Stawicki, Grossman, Hoey, Miller, & Reed III, 2004; Truitt et al., 2011) . The mean ISS across all 61 studies was 19.70 ± 6.82.

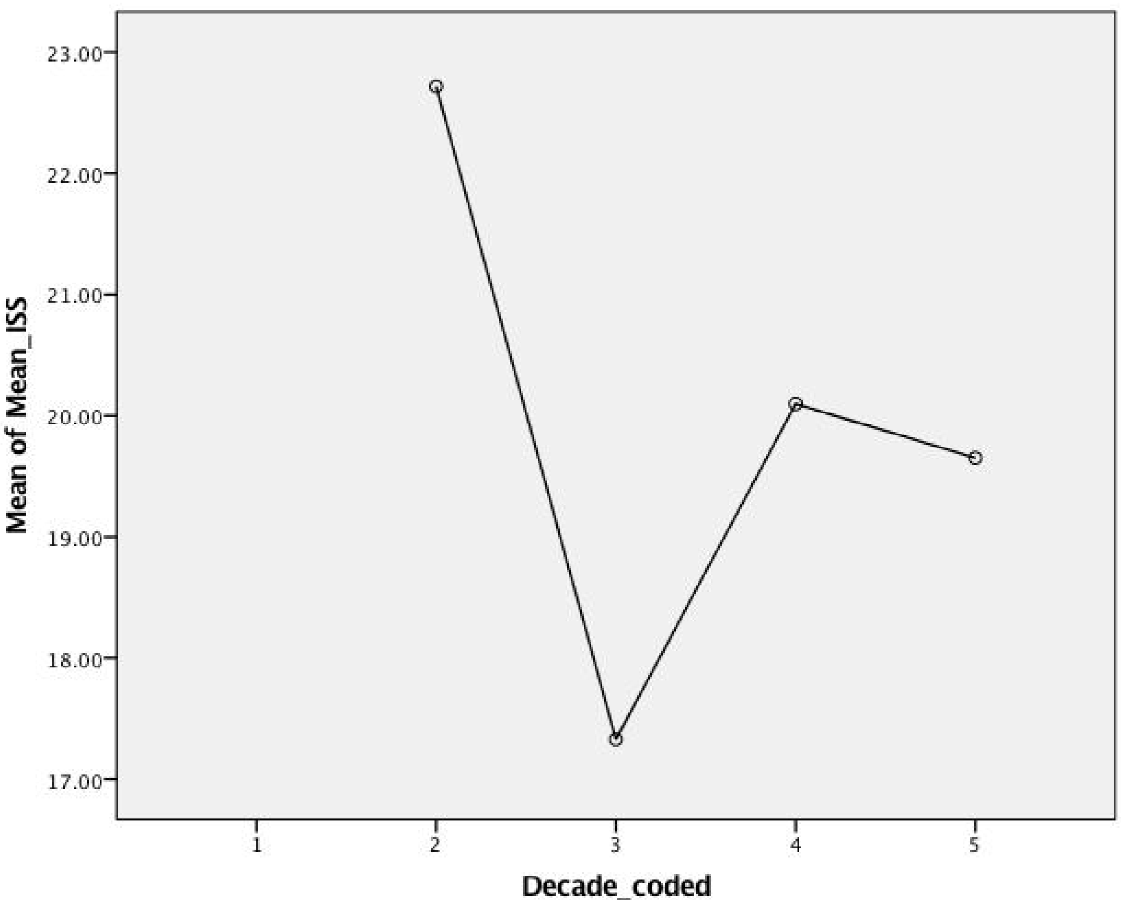

Figure 3: Mean plot of ISS across the 1970s, 1980s, 1990s, 2000s and 2010-18.

Incidence of flail chest. Flail chest is defined as three consecutive ribs fractured in two or more places (Nirula & JC, 2010). The most common range for the incidence of flail chest across all the examined studies was 15% -41% (Assi & Nazal, 2012; Bulger et al., 2000; Bulger et al., 2004; Mohta et al., 2009; Simpson et al., 2000; Truitt et al., 2011; Wu, Yang, Gao, Zhao, & He, 2015). Only one study in the 1970s had recorded the incident of flail chest and it had 42 occurrences (100%). Three out of the seven studies in the 1980s tracked this information and the average was 23 ± 14.73 flail chests (50.99%). Only one of the fourteen studies examined in the 1990s reported flail chest incidences and they had 7 cases (50.00%). In the 2000s, 19 out of 45 studies had this information and the average was 36.68 ± 56.46 flail chests (25.51%). Nearly half of the cases in the 2010s (25 out of 56 studies) reported the number of flail chests they had and the average was 499.68 ± 1576.69 (47.25%). Figure 4 shows how common flail chest injuries were across the five decades. It was very high in the 1970s and then lower and consistent amongst the other decades. The incidence of flail chest among all of the 48 studies was 271.57 ± 1139.97 (40.48%).

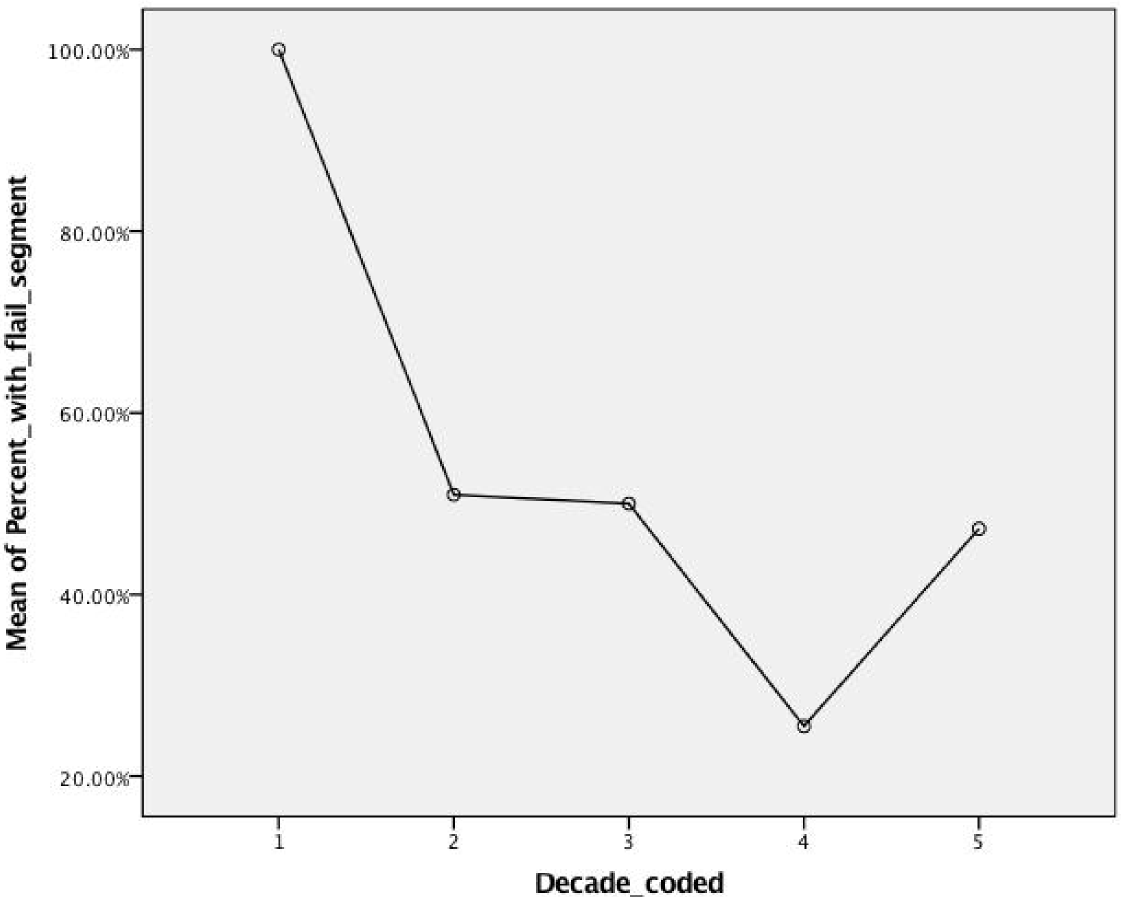

Figure 4: Mean plot of flail segments across the 1970s, 1980s, 1990s, 2000s and 2010-18.

Incidence of pulmonary contusion. A pulmonary contusion is a bruise of the lung and often accompanies rib fracture injuries. The expected incidence of pulmonary contusion is most commonly between 25 and 54% (Bergeron et al., 2003; Dehghan et al., 2014; Karmakar & Ho, 2003; Lu, Huang, Liu, Liu, & Kao, 2008; Shackford, Virgilio, & Peters, 1981). Only one study out of the three in the 1970s reported pulmonary contusions and this occurred in 11 (11%) of their patients. Two out of the seven studies in the 1980s tracked this and on average was found in 17.50 ± 2.12 (31.36%) of the patients. Five of the fourteen articles in the 1990s reported the incidence of pulmonary contusion and the average was 47.00 ± 78.38 (35.97%). In the 2000s, the average incidence of pulmonary contusions was 57.25 ± 61.93 (33.73%) and it was found in 20 of the 45 studies. In the 2010s, 18 out of the 56 studied reported the incidence of pulmonary contusions and the average was 325.06 ± 673.59 (52.64%). Pulmonary contusions have been more and more common every decade and this is depicted in figure 5. The average incidence across all 46 studies was 158.20 ± 438.15 (40.78%).

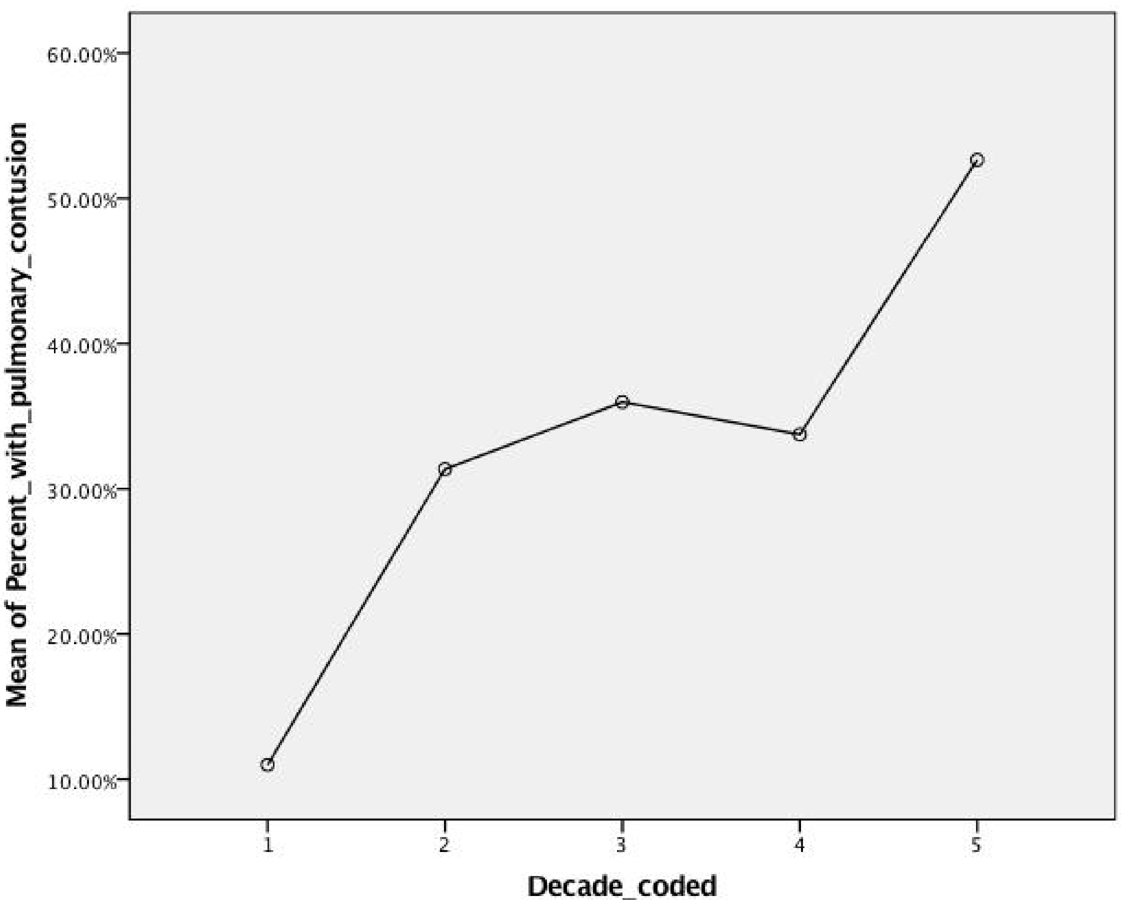

Figure 5: Mean plot of pulmonary contusion across the 1970s, 1980s, 1990s, 2000s and 2010-18.

Typical Outcomes of Patients with Rib Fractures

Mechanical ventilation. Mechanical ventilation is when a patient is unable to breathe efficiently on their own and needs a machine to help them breathe. Two of the studies in the 1970s recorded the number of patients requiring mechanical ventilation and the average percent was 26.50 ± 6.36 (74.84%). Four of the 1980s studies had this information and their average was 29.75 ± 36.12 (44.50%). In the 1990s the average was given in only two studies and was averaged to be 23.50 ± 13.44 (60.75%). Ten studies reported mechanical ventilation use in the 2000s and the average was 3932.80 ± 12250.26 (46.81%). In the 2010s, eleven studies recorded this data and the average was 1165.64 ± 3162.16 (18.87%). Figure 6 shows how the use of mechanical ventilation on rib fracture patients has gone down every decade with just a small rise 1990s. The average number of all patients that received mechanical ventilation was 1805.83 ± 7381.61 (38.79%).

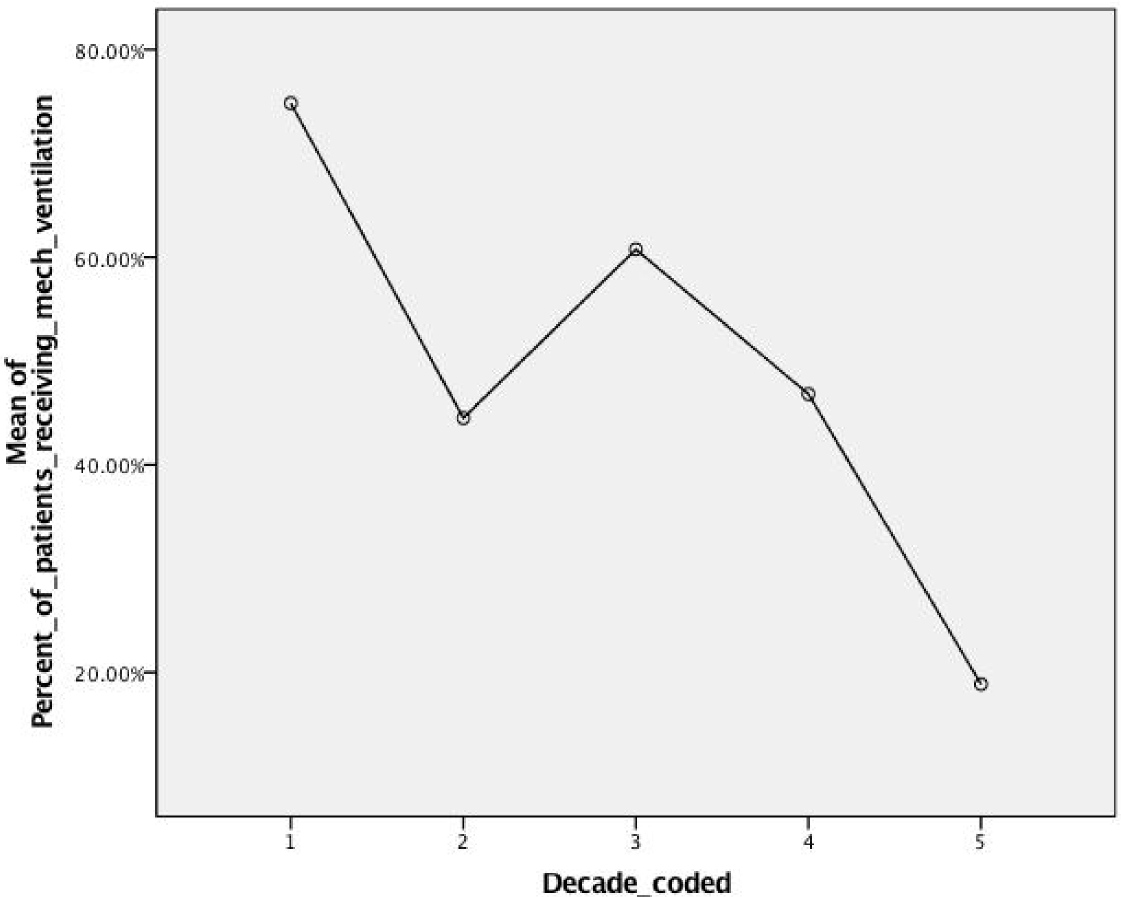

Figure 6: Mean plot of patients receiving mechanical ventilation across the 1970s, 1980s, 1990s, 2000s and 2010-18.

Pneumonia. Pneumonia is one of the many pulmonary complications seen among rib fracture patients (Bergeron et al., 2003; Brasel, Guse, Layde, & Weigelt, 2006; Byun & Kim, 2013; Sirmali et al., 2003). It is a common belief that pneumonia drastically increases the risk of mortality (Bergeron et al., 2003; Brasel et al., 2006). In the 1970s, only one study kept track of this and it was found in 17.00 (58.62%) of their patients. In the 1980s, three studies reported the incidences of pneumonia and their average was 14.67 ± 11.59 (27.10%) of their patients. The average for the 1990 studies was 18.25 ± 19.86 (14.01%) and this was from four of the studies. Seventeen of the studies in the 2000s had presented the number of pneumonia cases and the average was 83.06 ± 248.11 (15.82%). The occurrence of pneumonia in the 2010s was seen in seventeen studies and averaged to 359.50 ± 935.84 (17.06%) of the patients. Pneumonia rates were high in the 1970s but drastically dropped since then and have stayed that way. This can be seen in figure 7. The average number of patients that were diagnosed with pneumonia across all of the studies was 186.44 ± 632.95 (17.97%).

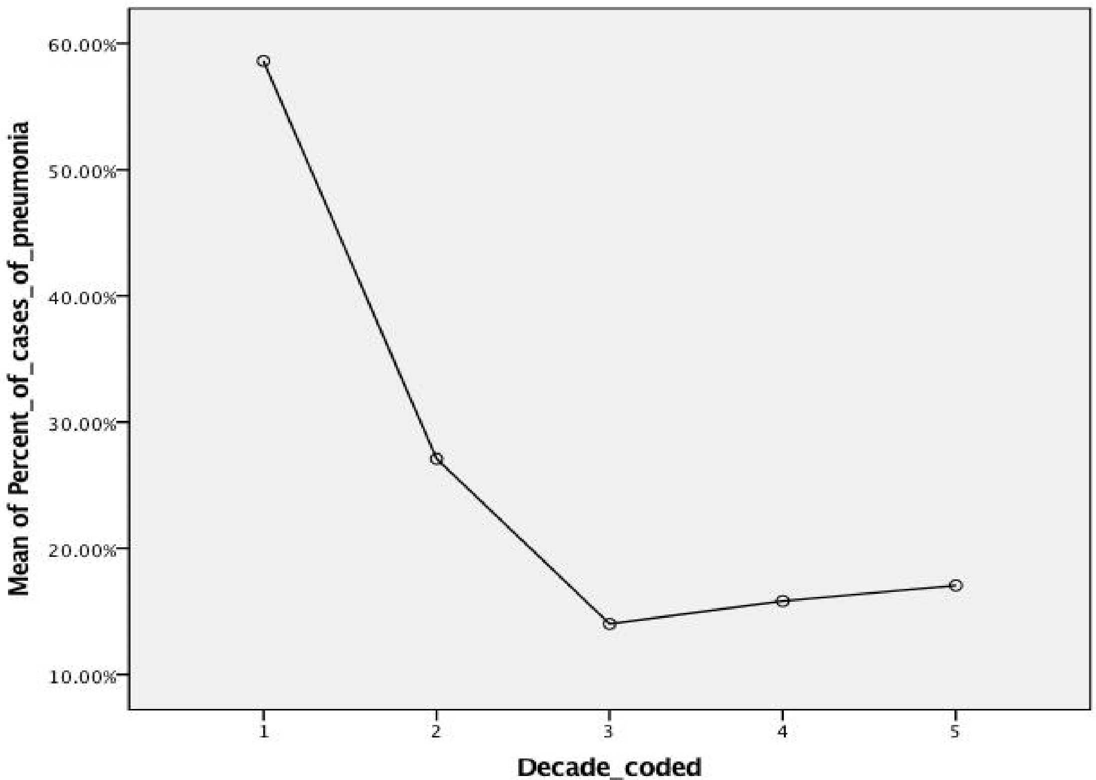

Figure 7: Mean plot of pneumonia across the 1970s, 1980s, 1990s, 2000s and 2010-18.

Mortality rate. Rib fractures can be very severe and even result in the loss of a patient. The risk of mortality can be increased by both the number of ribs fractured and the other associated injuries that come with it (Flagel et al., 2005; Yeh et al., 2012). The presence of secondary complications such as pneumonia and mechanical ventilation can also raise the chance of death dramatically (Ferguson & Luchette, 1996; Shackford, Smith, Zarins, Rice, & Virgilio, 1976; Shackford et al., 1981). If a patient presents with eight or more rib fractures then this rate can go beyond 30% (Flagel et al., 2005). All three studies from the 1970s recorded the mortality rates and the average was 4.33 ± 1.53 (10.36%). In the 1980s, the average rate of mortality was 69.75 ± 114.67 (10.16%) and was reported in four out of the seven studies. Only four out of the 14 studies in the 1990s had this information and the average was 44.75 ± 33.96 (9.38%). The average mortality rate in the 2000s was 586.33 ± 1615.75 (7.12%) and this was given in 21 of the 45 studies. The average in the studies in the 2010s was 299.15 ± 1059.07 (10.39%) and this was reported in 19 of the 56 studies. Figure 8 shows how mortality rates have stayed between 10 and 11 percent across all the decades except for a decrease in the 2000s.The average mortality rate amongst all of the studies was 360.90 ± 1219.37 (8.95%).

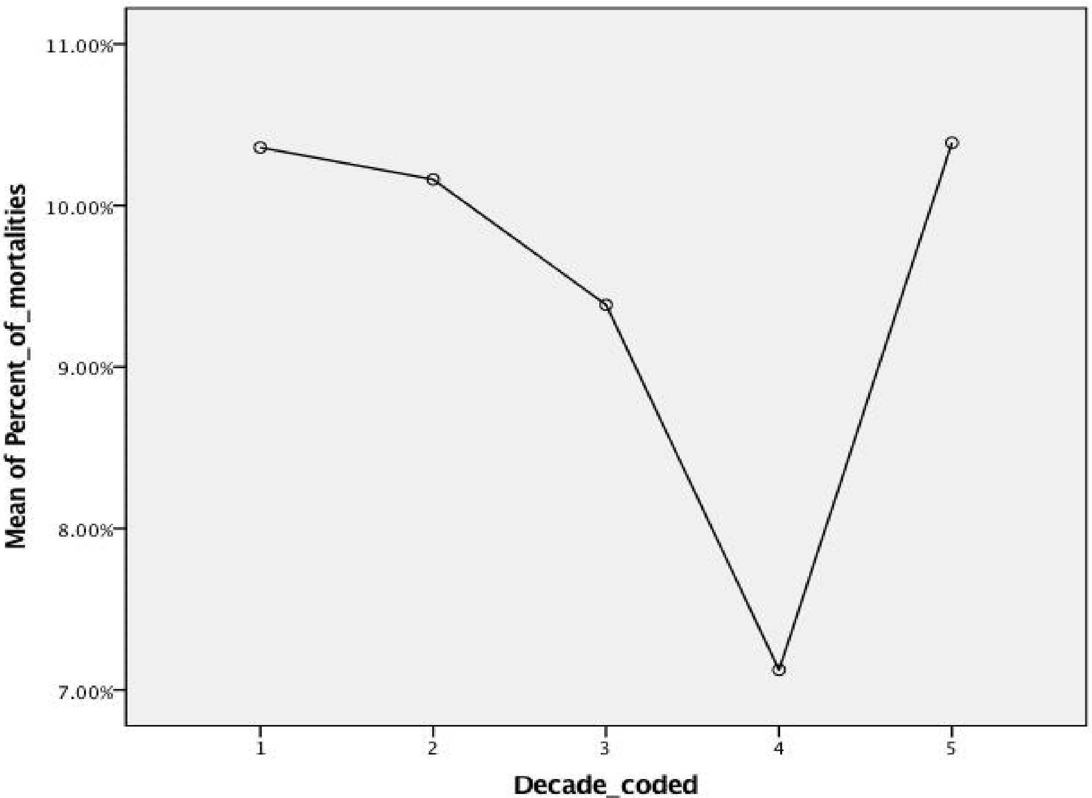

Figure 8: Mean plot of mortality across the 1970s, 1980s, 1990s, 2000s and 2010-18.

ICU LOS. The average length of stay in the ICU for patients with rib fractures ranged between 0.18 and 52.19 days. Only one study in both the 1970s and the 1980s reported ICU length of stay and the average days per patient was 52.19 days and 2.28 days respectively. Four studies in the 1990s had this data and the average was 5.53 ± 2.79 days. Fifteen of the 45 studies in the 2010s tracked the ICU length of stay and the average was 6.83 ± 5.99 days. The average was given in 23 of the 56 articles in the 2010s and the average was 6.98 ± 4.44 days. Figure 9 shows how the ICU LOS was very low except in the 1970s, but it only being reported in one study at the time means it cannot represent all patients at that time. The average length of stay in the ICU across all of the studies was 7.72 ± 8.37 days.

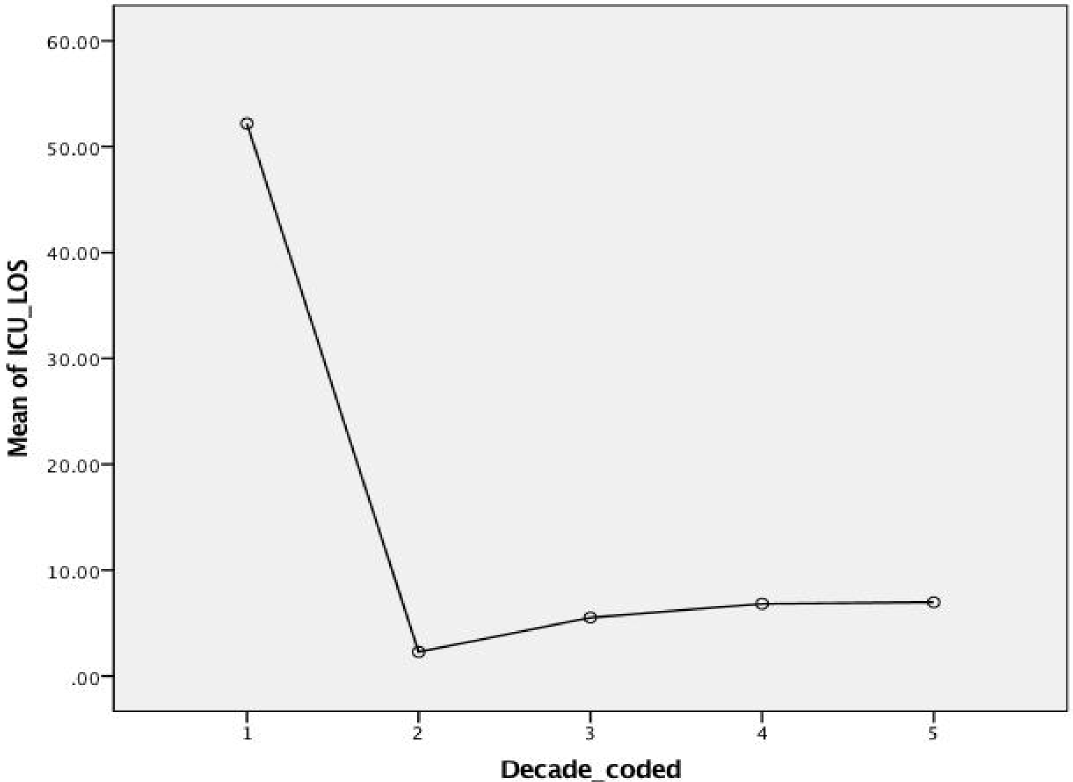

Figure 9: Mean plot of ICU LOS across the 1970s, 1980s, 1990s, 2000s and 2010-18.

Hospital LOS. The average length of stay in the hospital for patients with rib fractures ranged between 3 and 34 days. Only one of the three studies in the 1970s had the hospital length of stay and the average for their patients was 34.10 days. Four studies included this information in the 1980s and the average was 16.44 ± 10.79 days. Six of the studies in the 1990s gave this information and the average was 12.60 ± 2.99 days. The average hospital length of stay in the 2000s was given in 22 of the 45 studies and the average overall was 11.18 ± 6.28 days. In the 2010s, the average was reported in 29 of the 56 studies and came out to be 13.17 ± 7.01 days. Figure 10 shows a similar trend to ICU LOS but for hospital LOS. The average length is consistent among all decades except for the 1970s where it was much higher, but again only one study reported this information. The average length of stay in the hospital was 12.96 ± 7.20 days.

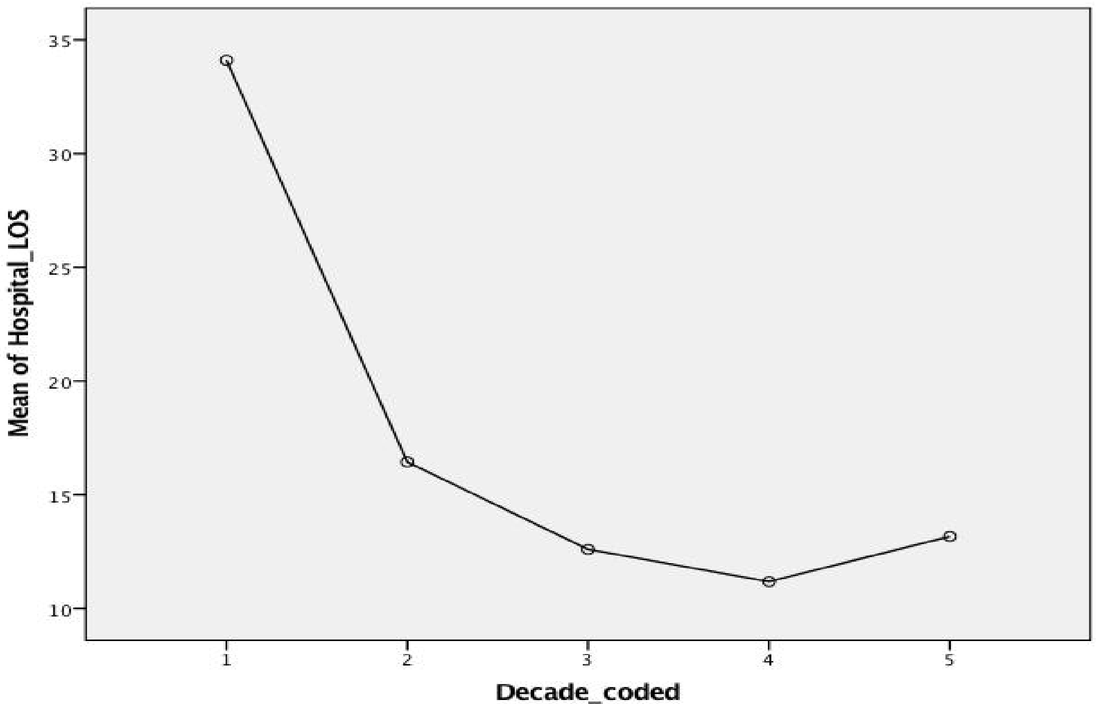

Figure 10: Mean plot of ISS across the 1970s, 1980s, 1990s, 2000s and 2010-18.

Cost of care. Rib fractures can be very costly for people. The cost can vary depending on the treatments the patient receives and whether or not they have surgery. The average cost for a patient who does not operate is between $34,000 and $37,100 (Granhed & Pazooki, 2014; Majercik et al., 2015). The cost for patients that do operate can vary depending on the type of operation they undergo. The average range starts around $13,400 and can be as high as $39,300 (Granhed & Pazooki, 2014; Majercik et al., 2015; Tanaka et al., 2002).

Differences across the 1970s, 1980s, 1990s, 2000s and 2010-18

After all of the averages were found by decade and for all 125 examined articles in total, further analyses were run to look at the differences of each variable across the decades. Table 2 shows the ANOVAs that were run and their results. The only variables that had statistically significant differences ($p<0.10$) were the average number of rib fractures ($p=0.093$), the percent of patients with pneumonia ($p=0.048$), the percent of patients that received mechanical ventilation ($p=0.007$), hospital LOS ($p=0.022$) and ICU LOS ($p<0.001$).

Table 2: ANOVAs for the descriptive variables

		Sum of Squares	df	Mean Square	F	Sig.
Age years	Between Groups	950.622	4	237.656	1.48	0.214
	Within Groups	15738.76	98	160.6		
	Total	16689.38	102			
Mean ISS	Between Groups	70.2	3	23.4	0.49	0.691
	Within Groups	2722.727	57	47.767		
	Total	2792.927	60			
Mean number ribs fractured	Between Groups	37.016	4	9.254	2.106	0.093
	Within Groups	237.228	54	4.393		
	Total	274.245	58			
Percent with flail segment	Between Groups	9144.359	4	2286.09	1.599	0.192
	Within Groups	61488.17	43	1429.958		
	Total	70632.53	47			
Percent with pulmonary contusion	Between Groups	4707.066	4	1176.767	1.963	0.118
	Within Groups	24574.94	41	599.389		
	Total	29282	45			

Percent of cases of pneumonia	Between Groups	2057.766	4	514.441	2.655	0.048
	Within Groups	7168.908	37	193.754		
	Total	9226.674	41			
Percent of patients receiving mech ventilation	Between Groups	8701.109	4	2175.277	4.582	0.007
	Within Groups	11392.71	24	474.696		
	Total	20093.82	28			
Hospital LOS	Between Groups	566.967	4	141.742	3.111	0.022
	Within Groups	2596.614	57	45.555		
	Total	3163.58	61			
ICU LOS	Between Groups	2050.79	4	512.698	20.852	0
	Within Groups	958.921	39	24.588		
	Total	3009.712	43			
Percent of mortalities	Between Groups	121.948	4	30.487	0.145	0.964
	Within Groups	9667.461	46	210.162		
	Total	9789.409	50			

Chapter 3: Methodology

This study was a retrospective analysis of a patient population treated at St. Vincent Hospital in Indianapolis, Indiana. All data were exported directly from the patient registry of the hospital's Level 1 trauma center. The registry was initially profiled for admissions that involve rib fracture injuries. This was accomplished by creating a search criterion that involved the International Statistical Classification of Diseases and Related Health Problems (ICD-10) code S22, which indicates sternal or rib fracture. After eliminating those who had isolated sternal fractures, involving no ribs, all remaining patients were considered the study population. Demographic information, injury characteristics, and treatment outcomes were exported for each of these patients and entered into the analyzable database. This showed age, race, ethnicity, sex, medications used prior to admission, anthropometric measurements (e.g., BMI), the number of ribs fractured, location of those fractures (e.g., unilateral or bilateral), the presence of associated injuries (e.g., flail chest, pulmonary contusion), vital signs and cardiorespiratory markers, methods of treatment (e.g., oral analgesics, TEA), adverse outcomes (e.g., pneumonia, respiratory distress syndrome), mortality, duration of care, and cost of care.

All analyses were done using Statistical Package for the Social Sciences version 24 (IBM SPSS Statistics, IBM Corporation, Chicago, IL, USA). All Dichotomous data (e.g., mortality) were analyzed with binary logistic regressions. Discrete data (e.g., cost of treatment) will be analyzed with linear regressions. Group means (TEA vs. non-TEA) were compared with independent samples t-tests; wherever Levene's test for equality of variances is significant, equal variances were not be assumed. Categorical data (e.g., inflection points) were compared with chi-square tests. After the analysis was complete, prediction equations were created.

Chapter 4: Draft of Manuscript

Title

Questioning the Cause of Mortality in Rib Fracture Patients

Abstract

Background. There are roughly 300,000 rib fractures treated for in the United States each year. These represent 10-26% of thoracic trauma injuries and have about a 10% mortality rate. There is a common belief that mortality in rib fracture patients can be contributed to the diagnosis of pneumonia, but this study does not support that claim. **Purpose.** To determine the predictors of morbidity and mortality in rib fracture patients. **Methods.** Using a level 1 trauma center patient registry, we retrospectively analyzed all patients that were admitted with at least one rib fracture (n=1,344). All predictors were analyzed with linear regressions. **Results.** The average age of the patients was 55.48 ± 20.29 years old and ranged between 15 and 98. ISS (OR: 1.0508, p<0.001), bilateral fractures (OR: 1.9495, p = 0.009) and pulmonary contusion (OR: 1.7481, p = 0.022) were all significant predictors of pneumonia. The age of the patient (OR: 1.0467, p < 0.001), ISS (OR: 1.0585, p <0.001), having 6 or more fractured ribs (OR: 3.1450, p < 0.001), the presence of hemothorax (OR: 2.5063, p = 0.048), and the use of mechanical ventilation (OR: 13.2125, p < 0.001) were all significant predictors of mortality. Flail segments (OR: 1.9871, p = 0.067), ISS (OR: 1.1267, p < 0.001), pulmonary contusions (OR: 1.5329, p = 0.047), pneumothorax (OR: 1.4372, p =0.073) and pneumonia (OR: 21.4516, p < 0.001) are all predictors of requiring mechanical ventilation. **Conclusion.** There are many studies that indicate rib fracture patients who are diagnosed with pneumonia have a higher risk or mortality. With this in mind, the logical course of treatment would be to counteract the complications

pneumonia brings as to reduce the risk or mortality. To do this, it is recommend the patient be put on mechanical ventilation. While this has been seen to help with pneumonia patients, this study provides evidence that health care professionals should look for ways to reduce the need for mechanical ventilation instead of using it to combat the pneumonia.

Introduction

Thoracic trauma is one of the leading causes of injury-related deaths in the United States, only surpassed by head injuries (Flagel et al., 2005). With nearly 300,000 rib fracture patients seen each year (Shuaib et al., 2013), they are the most commonly cared for chest wall injury (Lee et al., 1990; Sharma et al., 2008; Ziegler & Agarwal, 1994). Pneumonia is one of the many pulmonary comorbidities in rib fracture patients and is often associated with higher mortality rates (Bergeron et al., 2003; Brasel et al., 2006). One common way to develop pneumonia is from pain. The pain from a rib fracture negatively affects the breathing mechanics of the patient, preventing them from taking deep breaths (De Buck, Devroe, Missant, & Van de Velde, 2012). This means they will not be able to fully clear their lungs of sputum which can lead to the development of pneumonia (De Buck et al., 2012; Ferguson & Luchette, 1996). To help counteract the hypoxemia that pneumonia can induce, it is recommended that mechanical ventilation should be used (Zhang, Sun, & Feng, 2017). This is an effective treatment, but there are a multitude of studies suggesting that mechanical ventilation also leads to an increase in mortality rates (Ferguson & Luchette, 1996; Shackford et al., 1976; Shackford et al., 1981).

Knowing that a significant portion of mechanical ventilation patients are also diagnosed with pneumonia, it is easy to assume that pneumonia is the main cause of death in rib fracture patients. However, this was not the case in this study. These findings suggests that while pneumonia is still a strong predictor in mechanical ventilation, it may not be the leading cause of death amongst rib fracture patients. Instead, we found mechanical ventilation to be the largest correlated factor in predicting mortality.

Methods

This study was approved by both the IRB at University of the Pacific and St. Vincent Hospital. We retrospectively analyzed a data base of 1,344 patients that were admitted to our hospital with at least one rib fracture. Variables recorded include patient age, sex, injury severity score (ISS), numbers of ribs fractured, if the fracture was bilateral or not, presence of hemothorax, incidence of pneumonia, the use of thoracic epidural analgesia (TEA), if they died within 24 hours, the use of mechanical ventilation, and whether the patient smoked or not. These variables were analyzed through logistic regressions to see if any of them could be used to predict the need for mechanical ventilation, the presence of pneumonia, or death.

Results

There were 907 men and 437 women included in the study. The average age of the patients was 55.48 ± 20.29 years old ranging from 15 to 98 years old. The average ISS was 16.03 ± 10.43. The average number of ribs fractures was 4.00 ± 3.00 ribs. There were 193 patients (14.4%) who had bilateral rib fractures. There were 165 patients (12.3%) that had a hemothorax. Pneumonia was seen in 149 patients (11.1%). TEA was administered in 248 (18.5%) of the patients. There was a 6.7% mortality rate in our study. Mechanical ventilation was required in 320 patients (23.8%).

Pneumonia

A total of 149 patients were diagnosed with pneumonia. The average age of these patients was 53.56 ± 17.74 years old. Table 1 shows the regression used to predict the incidence on pneumonia. Out of the 5 variables used, ISS (OR: 1.0508, $p<0.001$), bilateral fractures (OR: 1.9495, $p = 0.009$) and pulmonary contusion (OR: 1.7481, $p = 0.022$) all increase the likelihood of getting pneumonia. Of these three, having a bilateral rib fracture is the strongest contributor followed by having a pulmonary contusion. The sex of the patient (OR: 0.5696, $p = 0.02$) and mortality within 24 hours (OR: 0.0404, $p = 0.018$) lower the chance of being diagnosed with pneumonia.

Table 1: Logistic regression predicting **incidence of pneumonia**.

Variable	***Odds Ratio***	***Standard Error***	***Z***	***Significance***	***95% Confidence Interval***
Injury Severity Score	1.0508	0.0094	5.53	P < 0.001	1.0325 to 1.0694
Presence of bilateral fractures	1.9495	0.4980	2.61	P = 0.009	1.1816 to 3.2164
Presence of a pulmonary contusion	1.7481	0.4275	2.28	P = 0.022	1.0824 to 2.8231
Patient's sex	0.5696	0.1374	–2.33	P = 0.02	0.3550 to 0.9139
Mortality within 24 hours	0.0404	0.0549	–2.36	P = 0.018	0.0028 to 0.5797
Constant	0.0270	0.0104	–9.39	P < 0.001	0.0127 to 0.0573

Model Summary	Observations	Wald Chi ^{2}	Prob > Chi ^{2}	Log Pseudo-likelihood	Pseudo R^2
	1,299	106.580	P < 0.001	–390.627	0.120

Table 1: Significant ($p < 0.05$) and trending ($p < 0.08$) predictors of pneumonia are listed above. Other non-significant variables controlled for were: use of thoracic epidural analgesia, presence of 6 or more rib fractures, a flail segment, hemothorax, pneumothorax, mechanism of injury (auto accidents, motorcycle accidents, falls, other), age, smoking status, obesity, and race/ethnicity.

Mechanical Ventilation

There were 320 patients that required mechanical ventilation in this study. The average age of these patients was 50.99 ± 19.51 years old. Table 2 shows the results of the regression used to predict the use of mechanical ventilation. Flail segments (OR: 1.9871, p = 0.067), ISS (OR: 1.1267, p < 0.001), pulmonary contusions (OR: 1.5329, p = 0.047), pneumothorax (OR: 1.4372, p =0.073) and pneumonia (OR: 21.4516, p < 0.001) all increase the chance of being put on mechanical ventilation. Pneumonia increases this chance by a 21 fold increase whereas the other variables are only a one or two fold increase. The sex of the patient (OR: 0.6286, p = 0.024), use of TEA (OR: 0.3942, p<0.001), smoking status (OR: 0.4976, p=0.001), and the mechanism of injury being on a motorcycle (OR: 0.5457, p = 0.032) or falling (OR: 0.5760, p = 0.021) lowers the chance of requiring mechanical ventilation.

Table 2: Logistic regression predicting **use of mechanical ventilation**.

Variable	*Odds Ratio*	*Standard Error*	*Z*	*Significance*	*95% Confidence Interval*
Patient's sex	0.6286	0.1293	–2.26	P = 0.024	0.4200 to 0.9407
Injury Severity Score	1.1267	0.0145	9.27	P < 0.001	1.0987 to 1.1555
Presence of a flail segment	1.9871	0.7456	1.83	P = 0.067	0.9524 to 4.1459
Presence of a pulmonary contusion	1.5329	0.3302	1.98	P = 0.047	1.0050 to 2.3380
Presence of a pneumothorax	1.4372	0.2912	1.79	P = 0.073	0.9661 to 2.1380
Incidence of pneumonia	21.4516	6.4339	10.22	P < 0.001	11.9169 to 38.6151
Use of thoracic epidural analgesia	0.3942	0.1006	–3.65	P < 0.001	0.2390 to 0.6500
Smoking status	0.4976	0.1081	–3.21	P = 0.001	0.3250 to 0.7618
Mechanism: motorcycle	0.5457	0.1542	–2.14	P = 0.032	0.3136 to 0.9496
Mechanism: fall	0.5760	0.1378	–2.31	P = 0.021	0.3604 to 0.9205
Constant	0.0292	0.0131	–7.86	P < 0.001	0.0121 to 0.0705
Model Summary	**Observations**	**Wald Chi ^{2}**	**Prob > Chi ^{2}**	**Log Pseudo-likelihood**	**Pseudo R ^{2}**
	1,295	231.570	P < 0.001	–436.166	0.385

Table 2: Significant ($p < 0.05$) and trending ($p < 0.08$) predictors of mechanical ventilation are listed above. Other non-significant variables controlled for were: age, race/ethnicity, obesity, presence of 6 or more rib fractures, bilateral fractures, hemothorax, mortality within 24 hours, and other mechanisms of injury relative to auto accidents.

Mortality

There were 90 patients that died in this study. The average age of these patients was 59.39 ± 22.25 years old. Table 3 shows the results of the regression done to predict mortality. The age of the patient (OR: 1.0467, p < 0.001), ISS (OR: 1.0585, p <0.001), having 6 or more fractured ribs (OR: 3.1450, p < 0.001), the presence of hemothorax (OR: 2.5063, p = 0.048), and the use of mechanical ventilation (OR: 13.2125, p < 0.001) all increase the likelihood of mortality amongst rib fracture patients. Pneumonia (OR: 0.0969, p < 0.001), TEA (OR: 0.0552p = 0.001) and smoking status (OR: 0.4209, p = 0.074) all lower the chance of mortality.

Table 3: Logistic regression predicting **mortality**.

Variable	***Odds Ratio***	***Standard Error***	***Z***	***Significance***	***95% Confidence Interval***
Patient's age in years	1.0467	0.0106	4.52	P < 0.001	1.0262 to 1.0677
Injury Severity Score	1.0585	0.0146	4.13	P < 0.001	1.0303 to 1.0875
Presence of 6 or more rib fractures	3.1450	0.9642	3.74	P < 0.001	1.7244 to 5.7357
Presence of a hemothorax	2.5063	1.1634	1.98	P = 0.048	1.0090 to 6.2253
Incidence of pneumonia	0.0969	0.0558	–4.05	P < 0.001	0.0313 to 0.2996
Use of thoracic epidural analgesia	0.0552	0.0488	–3.27	P = 0.001	0.0097 to 0.3125

Use of mechanical ventilation	13.2125	4.9052	6.95	P < 0.001	6.3822 to 27.3525
Smoking status	0.4209	0.2042	–1.78	P = 0.074	0.1627 to 1.0893
Constant	0.0007	0.0006	–8.33	P < 0.001	0.0001 to 0.0038
Model Summary	**Observations**	**Wald Chi ^{2}**	**Prob > Chi ^{2}**	**Log Pseudo-likelihood**	**Pseudo R ^{2}**
	1,295	180.320	P < 0.001	–187.770	0.401

Table 3: Significant ($p < 0.05$) and trending ($p < 0.08$) predictors of mortality are listed above. Other non-significant variables controlled for were: sex, race/ethnicity, and obesity, presence of bilateral fractures, a flail segment, pulmonary contusion, pneumothorax, and mechanisms of injury.

Discussion

Because thoracic trauma being one of the most prominent causes of injury related deaths in America it is crucial to understand how it leads to death in so many patients (Flagel et al., 2005). Among all the thoracic trauma injuries, rib fractures are the most commonly seen chest wall injury (Lee et al., 1990; Sharma et al., 2008; Ziegler & Agarwal, 1994). It is clear that rib fracture patients with pneumonia have a higher rate of mortality than those without it (Bergeron et al., 2003; Brasel et al., 2006). To help prevent some of the negative effects of pneumonia, mechanical ventilators are often used to help them breathe (De Buck et al., 2012). Several studies have also reported that being put on mechanical ventilation increases the mortality rate (Ferguson & Luchette, 1996; Shackford et al., 1976; Shackford et al., 1981). With all of this being so well known it is easy to assume that pneumonia is the actual cause of increased mortality. This study also indicates that the chance of being put on mechanical ventilation does indeed increase significantly when the patient has pneumonia. Where this study disagrees with the assumption, is that it is not the pneumonia that increases the chance of death, but rather whether or not the patients undergo mechanical ventilation. Holding all other variables constant, the patients that had pneumonia actually had a lower mortality rate while mechanical ventilation significantly increased the odds of death.

This is important to know because it can help improve patient outcomes when they are diagnosed with rib fractures. Instead of focusing on trying to prevent them from getting pneumonia, medical professionals can now shift their focus to preventing them from being put on mechanical ventilation. If these are reliable predictors of mortality then avoiding those events can help further reduce the chance of death amongst all rib fracture patients. This will allow for further research to look into how specifically mechanical ventilation increases mortality without looking at pneumonia. A few limitations to this study are that the study is not a randomized control trial and all subjects are from a level 1 trauma center.

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APPENDIX A: META-ANALYSIS TABLE

First Author	Year	Decade	Decade coded	N	Age in years	Age StDev	Sex number men	Sex percent men	Sex number women	Sex percent women
Abouhatem	1984	1980s	2	19	53					
Al-Hassani	2010	2010s	5	310			296	95.48%	14	4.52%
Alkadhi	2004	2000s	4	30						
Allen	2009	2000s	4	124	64.7		65	52.42%	59	47.58%
Althausen	2011	2010s	5	60	49.44		40	66.67%	11	18.33%
Bakhos	2006	2000s	4	38	80.2	7.4	13	34.21%	25	65.79%
Balci	2004	2000s	4	64	32.6		48	75.00%	16	25.00%
Bansal	2011	2010s	5	287			124	43.21%	163	56.79%
Bansidhar	2002	2000s	4	209	52	20	128	61.24%	81	38.76%
Barnea	2002	2000s	4	77	79.9	7.9	40	51.95%	37	48.05%
Barrett-Connor	2010	2010s	5	126			126	100.00%	0	0.00%
Bayouth	2013	2010s	5	42	52.5	15	30	71.43%	12	28.57%
Bergeron	2003	2000s	4	405	51.2	20.4	268	66.17%	137	33.83%
Bille	2012	2010s	5	18			12	66.67%	6	33.33%
Bollinger	1990	1990s	3	69	47.05	15.3	48	69.57%	21	30.43%
Byun	2013	2010s	5	418			327	78.23%	91	21.77%
Bulger	2000	2000s	4	464	59.89		289	62.28%	175	37.72%
Bulger	2004	2000s	4	46	47.5		33	71.74%	13	28.26%
Brasel	2006	2000s	4	17,308	56		10133	58.55%	7171	41.43%
Cameron	1996	1990s	3	541	47.5	21.01				
Campbell	2009	2000s	4	32			23	71.88%	9	28.13%
Chalumeau	2002	2000s	4	5	0.25		1	20.00%	0	0.00%
Cho	2012	2010s	5	130	49.3		102	78.46%	28	21.54%
Cicala	1990	1990s	3	14						
Clark	1988	1980s	2	144	40	18	97	67.36%	47	32.64%
D'Arcy	2005	2000s	4	1	66		1	100.00%	0	0.00%
de Moya	2011	2010s	5	48	46.33	8.87	40	83.33%	8	16.67%
DeFreest	2016	2010s	5	86	53.68		71	82.56%	15	17.44%
Dehghan	2014	2010s	5	3467	52.5		2670	77.01%	797	22.99%
Dittman	1978	1970s	1	100	51.42					
Doben	2014	2010s	5	21	52.22	15.86	16	76.19%	5	23.81%
Dolinak	2007	2000s	4	8			3	37.50%	5	62.50%
Doss	1999	1990s	3	57			39	68.42%	18	31.58%
Dragoni	2007	2000s	4	9	24.4		9	100.00%	0	0.00%
Elmistekawy	2007	2000s	4	39	66.8	4.7	28	71.79%	11	28.21%
Fabricant	2013	2010s	5	203			145	71.43%	58	28.57%
Fabricant	2014	2010s	5	24	48	12	17	70.83%	7	29.17%
Farquhar	2016	2010s	5	55	55.33	15.36	40	72.73%	15	27.27%
Flagel	2005	2000s	4	64,661	49.5					
Gipson	2006	2000s	4	1	0.06		1	100.00%	0	0.00%
Gonzales	2015	2010s	5	399						
Govindarajan	2002	2000s	4	27	48		23	85.19%	4	14.81%
Granhed	2014	2010s	5	60	57		44	73.33%	16	26.67%
Griffith	1999	1990s	3	50	50		33	66.00%	17	34.00%
Hakim	2012	2010s	5	55	40		32	58.18%	23	41.82%
Hanak	2005	2000s	4	54	55	17	12	22.22%	42	77.78%
Harrington	2012	2010s	5	1621	70.1		952	58.73%	669	41.27%
Hashemzadeh	2011	2010s	5	60	55.48		55	91.67%	5	8.33%
Hickey	1997	1990s	3	17	21.7		2	11.76%	15	88.24%
Ho	2014	2010s	5	58	49.7	28.5	40	68.97%	18	31.03%
Holcomb	2003	2000s	4	171	42		123	71.93%	48	28.07%
Hurley	2004	2000s	4	14	31		11	78.57%	3	21.43%
Hwang	2014	2010s	5	54	45.5		44	81.48%	10	18.52%
Ingalls	2010	2010s	5	58	52.6	3.49	33	56.90%	15	25.86%
Ioannidis	2009	2000s	4	147			45	30.61%	102	69.39%
Jensen	2017	2010s	5	1,344	55.5	20.3	907	67.49%	437	32.51%
Johnston	1980	1980s	2	6	49					
Kaiser	1998	1990s	3	30	58		21	70.00%	9	30.00%
Kane	2017	2010s	5	687,137	45.9	29.94	469,109	68.27%	218,028	31.73%
Karadayi	2011	2010s	5	214	51.5		173	80.84%	41	19.16%
Karlson	1998	1990s	3	10			3	30.00%	7	70.00%
Karmakar	2003	2000s	4	15	52.8		11	73.33%	4	26.67%
Katrancioglu	2015	2010s	5	12	55.9	12.2	7	58.33%	5	41.67%
Keech	2015	2010s	5	1	4		1	100.00%	0	0.00%
Kerr-Valentic	2003	2000s	4	40	52	18	27	67.50%	13	32.50%
Kessel	2014	2010s	5	6,955			5,231	75.21%	1,624	23.35%

APPENDIX B: META-ANALYSIS TABLE CONTINUED

First Author	Year	Decade	Decade coded	N	Age in years	Age StDev	Sex number men	Sex percent men	Sex number women	Sex percent women
Khandelwal	2011	2010s	5	61	46.29		40	65.57%	21	34.43%
Kieninger	2005	2000s	4	187	77		72	38.50%	115	61.50%
Kim	2011	2010s	5	26	61	15	14	53.85%	12	46.15%
Kim	2011	2010s	5	35	54		23	65.71%	12	34.29%
Labbe	2009	2000s	4	11	38.6		5	45.45%	6	54.55%
Lederer	2004	2000s	4	19	66.4	16.3	13	68.42%	6	31.58%
Lee	1989	1980s	2	3282	28.8	20.11	2,249	68.53%	1,033	31.47%
Lien	2009	2000s	4	18,856	53.6	15.6	13,217	70.09%	5,639	29.91%
Livingston	2008	2000s	4	388	44		301	77.58%	87	22.42%
Love	2004	2000s	4	43			26	60.47%	17	39.53%
Lu	2008	2000s	4	295	54.63		207	70.17%	88	29.83%
Luchette	1994	1990s	3	19	53.5					
Mackersie	1991	1990s	3	32	48.55					
Majercik	2014	2010s	5	151	57	2	116	76.82%	35	23.18%
Marasco	2013	2010s	5	46	58.55		40	86.96%	6	13.04%
Marasco	2015	2010s	5	397	53.9	18.8	298	75.06%	99	24.94%
Matos	2009	2000s	4	46			26	56.52%	20	43.48%
Matshes	2010	2010s	5	5	0.2		3	60.00%	2	40.00%
Maxwell	2012	2010s	5	81			52	64.20%	29	35.80%
Mayberry	2003	2000s	4	10	44					
Mayberry	2009	2000s	4	46	50		36	78.26%	10	21.74%
McKendy	2017	2010s	5	1360	54.2	19.7	925	68.01%	435	31.99%
Mohta	2009	2000s	4	30	39.65		24	80.00%	6	20.00%
Nakae	2012	2010s	5	162	63		72	44.44%	90	55.56%
Nickerson	2015	2010s	5	89			66	74.16%	23	25.84%
Nirula	2006	2000s	4	60	51.1					
Oncel	2002	2000s	4	100	40	16	59	59.00%	41	41.00%
Osinowo	2004	2000s	4	21	51.9	15.6	18	85.71%	3	14.29%
Paik	2005	2000s	4	37						
Park	2012	2010s	5	453	52.8		323	71.30%	130	28.70%
Pulley	2015	2010s	5	35	54.1		25	71.43%	10	28.57%
Sahr	2013	2010s	5	148	79.6	8.602	76	51.35%	72	48.65%
Sajjan	2012	2010s	5	4,758			0	0.00%	4,758	100.00%
Shackford	1976	1970s	1	42	43		40	95.24%	2	4.76%
Shackford	1981	1980s	2	36	39.2	4.3	26	72.22%	10	27.78%
Shanti	2001	2000s	4	161			111	68.94%	50	31.06%
Sharma	2008	2000s	4	808	43.1					
Shinohara	1994	1990s	3	17	50.3		15	88.24%	2	11.76%
Short	1996	1990s	3	15			10	66.67%	5	33.33%
Shulzhenko	2017	2010s	5	67,659	76.8	7.7	36,966	54.64%	30,715	45.40%
Shweiki	2001	2000s	4	476	47.8	21.5				
Sirmali	2003	2000s	4	548	43		331	60.40%	217	39.60%
Solak	2013	2010s	5	45	48.3	11.9	27	60.00%	18	40.00%
Solberg	2009	2000s	4	16	39.8	15.11	11	68.75%	5	31.25%
Stawicki	2004	2000s	4	27,855			17,665	63.42%	10,190	36.58%
Szucs-Farkas	2011	2010s	5	39	64.2	14.2	32	82.05%	7	17.95%
Tanaka	2002	2000s	4	37	44.54	10.46	26	70.27%	11	29.73%
Tarng	2015	2010s	5	12	47.3	14.37	11	91.67%	1	8.33%
Taylor	2013	2010s	5	21	51.5		14	66.67%	7	33.33%
Testerman	2006	2000s	4	307	49		212	69.06%	95	30.94%
Trinkle	1975	1970s	1	29	40.5		18	62.07%	11	37.93%
Truitt	2010	2010s	5	30	65					
Truitt	2011	2010s	5	102	69					
Turk	2010	2010s	5	18			15	83.33%	3	16.67%
Ullman	1989	1980s	2	28	49.55		22	78.57%	6	21.43%
Van Staa	2001	2000s	4	17384			10,256	59.00%	7,128	41.00%
Velmahos	2002	2000s	4	90	49.49	18.37	71	78.89%	19	21.11%
Vinther	2005	2000s	4	7	25.6		5	71.43%	2	28.57%
Waqar	2013	2010s	5	85	47		64	75.29%	21	24.71%
Whitson	2013	2010s	5	35,468	45.8	19.4	24,260	68.40%	11,226	31.65%
Wilson	2012	2010s	5	1	0.06		0	0.00%	1	100.00%
Wisner	1990	1990s	3	307	70.1		120	39.09%	187	60.91%
Worthley	1985	1980s	2	161	46.1		123	76.40%	38	23.60%
Wu	1999	1990s	3	64	50.5		33	51.56%	31	48.44%
Wu	2015	2010s	5	164	51.5	3.8	164	100.00%	0	0.00%
Wuermser	2011	2010s	5	699	55.15	19.7	348	49.79%	351	50.21%
Yeh	2012	2010s	5	187	50.1		139	74.33%	48	25.67%
Ziegler	1994	1990s	3	711	51		411	57.81%	300	42.19%

APPENDIX C: META-ANALYSIS TABLE CONTINUED

First Author	Mean number ribs fractured	Mean number ribs fractured StDev	Number with flail segment	Percent with flail segment	Number with pulmonary contusion	Percent with pulmonary contusion	Mean ISS	Mean ISS StDev	Hospital LOS	ICU LOS
Abouhatem	5		7	37%					6.4	
Al-Hassani	4				215	69%				
Alkadhi			2	7%						
Allen										
Althausen	6.68				50	83%	24.65		10.51	8.42
Bakhos	3.6	1.6					6.9	4.7	4.5	1.3
Balci			64	100%	29	45%	19.7		18.8	
Bansal			41	14%						
Bansidhar			11	5%	65	31%	8	4	5	0.94
Barnea	2.6				13	17%			4.5	4.5
Barrett-Connor										
Bayouth	4.5	2.5					14	5.5	4.9	
Bergeron					108	27%			26.8	
Bille									3.67	
Bollinger	6.9	2.25			11	16%	12.9	4.75	11.37	7.31
Byun			10	2%	92	22%			22.95	7.74
Bulger	3.76		69	15%	130	28%	20.98		13.5	
Bulger	7		13	28%	22	48%	25.5		17	
Brasel							13.1			
Cameron							16		16.16	
Campbell					15	47%	26	9.5	13.5	3
Chalumeau	4									
Cho										
Cicala			7	50%	7	50%				
Clark							32	14		
D'Arcy	6.5									
de Moya	8	3.33	20	42%	5	10%	24.67	8.35	16.67	7.67
DeFreest	10.89		86	100%	62	72%	28.44		20.29	10.86
Dehghan			3467	100%	1872	54%	30.4		16.6	11.7
Dittman	6.65				11	11%			N/A	52.19
Doben	8.88		21	100%			31.22	11.18	25.21	13.97
Dolinak										
Doss										
Dragoni										
Elmistekawy	1.84	0.7			8	21%			7.6	1.64
Fabricant	5.4		15	7%			20		8.3	3.8
Fabricant										
Farquhar			55	100%	40	73%	30.03	8.61	18.05	4.98
Flagel			252	0%			19.9		7	4
Gipson	8		1	100%						
Gonzales	4.48				150	38%	15.07			
Govindarajan	4								5	N/A
Granhed	6.3		56	93%	45	75%	21.7	10.8		
Griffith										
Hakim			2	4%					N/A	5
Hanak										
Harrington	3.7						11.7		27.5	16.5
Hashemzadeh									6.7	1.74
Hickey										
Ho	3.5	1.15					2.8	0.7	N/A	0.3
Holcomb	3.6		18	11%	53	31%	16		8.5	3
Hurley										
Hwang	3.92								9.89	
Ingalls	5.13	0.4					17.56	1.3	7.11	
Ioannidis										
Jensen	4	3	97	7%	267	20%	16	10.426	7.7	7.16
Johnston	5									
Kaiser									15.4	3.1
Kane	3.72	2.31	7306	1%			16.12	11.5		
Karadayi			6	3%	14	7%				
Karlson										
Karmakar	5		1	7%	4	27%				
Katrancioglu									4	
Keech	9									
Kerr-Valentic	2.7	1.6							5	
Kessel					2405	35%				

APPENDIX D: META-ANALYSIS TABLE CONTINUED

First Author	Mean number ribs fractured	Mean number ribs fractured StDev	Number with flail segment	Percent with flail segment	Number with pulmonary contusion	Percent with pulmonary contusion	Mean ISS	Mean ISS StDev	Hospital LOS	ICU LOS
Khandelwal	3.23		2	3%						
Kieninger							9.3		6.45026738	
Kim	7									
Kim	1.7									
Labbe										
Lederer										
Lee							13.75	11.9	9.37	2.28
Lien			66	0%						
Livingston	4.2		22	6%	187	48%	21			
Love										
Lu					75	25%			7.66	
Luchette					11	58%	20.55			
Mackersie	4.5						18		7.85	
Majercik	6.3	0.23	99	66%			21.33	1.3		
Marasco	11.1		46	100%	41	89%	32.5		22.5	
Marasco			211	53%			22.5	11.8	16.2	
Matos	2.68	2.33								
Matshes	5									
Maxwell									12.1	5.1
Mayberry			5	50%	2	20%	24			
Mayberry		3.1	18	39%			30	12		
McKendy	4.8	3.3	138	10%	376	28%	19.9	8.9	15.2	6.8
Mohta	4.9		5	17%	5	17%	14.75		10.9	6.55
Nakae							1			
Nickerson			38	43%			17.96		9	1
Nirula			24	40%			26.6		19.95	13.1
Oncel	1.8	0.8								
Osinowo	3.57	1.5	0							
Paik										
Park										
Pulley	12.5	4.8	35	100%			22			
Sahr									7.71	2.92
Sajjan										
Shackford	4.7		42	100%						
Shackford	5.4	0.5	36	100%	19	53%	N/A	N/A	19.89	
Shanti										
Sharma			36	4%	218	27%	23.6		7.9	
Shinohara	5.7									
Short										
Shulzhenko			631	1%			14.4	9.32	7.9	6.9
Shweiki							20.8	12.9		
Sirmali			32	6%	94	17%			16.8	11.8
Solak	5	1.67			18	40%				
Solberg					8	50%	24.86	6.37	N/A	12.23
Stawicki							22.02		12.34	4.86
Szucs-Farkas										
Tanaka	8.2	2.94	37	100%	37	100%	31.5	9.46	N/A	21.79
Tarng	7.33	1.15	9	75%	12	100%	21.17	4.13	15.17	8
Taylor	6		21	100%					14.6	5.2
Testerman	6.5				39	13%	17.4		7.6	2.1
Trinkle	5.85								34.1	
Truitt	4.4						14			
Truitt	5.8						14		2.9	
Turk										
Ullman	6.96						22.4		30.1	
Van Staa										
Velmahos			22	24%	33	37%	20.22	11.18	19.69	11.69
Vinther	2.4									
Waqar	5.8		14	16%	34	40%	22.3		19.9	12.9
Whitson							19.9	13.2		
Wilson	2									
Wisner							13.7			
Worthley			26	16%	16	10%				
Wu	5				19	30%	21.75		12.2	3.2
Wu	8		66	40%	153	93%			21.4	11.7
Wuermser										
Yeh	6.05						22.55		7.2	0.18
Ziegler					187	26%	18.4		12.6	8.5

APPENDIX E: META-ANALYSIS TABLE CONTINUED

First Author	Number of cases of pneumonia	Percent of cases of pneumonia	Number of patients receiving mech ventilation	Percent of patients receiving mech ventilation	Mean duration of ventilation	Number of mortalities	Percent of mortalities
Abouhatem	7	37%	5	26%		0	0%
Al-Hassani							
Alkadhi							
Allen							
Althausen	8	13%			8.07		
Bakhos	1	3%				1	3%
Balci	5	8%	21	33%	5.4	4	6%
Bansal							
Bansidhar						40	19%
Barnea	10	13%				6	8%
Barrett-Connor							
Bayouth							
Bergeron	69	17%	116	29%		49	12%
Bille							
Bollinger	21	30%	33	48%		2	3%
Byun	18	4%	50	12%	9.18	22	5%
Bulger	118	25%	251	54%	3.81	32	7%
Bulger	13	28%	29	63%	8.5	3	7%
Brasel	1038	6%				692	4%
Cameron						53	10%
Campbell	3	9%					
Chalumeau	1	20%					
Cho							
Cicala							
Clark	28	19%	83	58%	10.4	36	25%
D'Arcy							
de Moya	17	35%			6.33		
DeFreest	21	24%			7.47	6	7%
Dehghan	713	21%	1762	51%	12.1	544	16%
Dittman						3	3%
Doben					13.33	0	0%
Dolinak							
Doss							
Dragoni							
Elmistekawy			3	8%		4	10%
Fabricant			50	25%		5	2%
Fabricant							
Farquhar	20	36%			4.14	2	4%
Flagel	3-5.2% 6+ ribs: 6.8-8.4%		38797	60%	13	6544	10%
Gipson							
Gonzales							
Govindarajan							
Granhed	0		21	35%	2.7	2	3%
Griffith							
Hakim	13	24%	11	20%	5.5		
Hanak							
Harrington	64	4%				75	5%
Hashemzadeh							
Hickey							
Ho							
Holcomb	11	6%			2.4	3	2%
Hurley							
Hwang							
Ingalls							
Ioannidis							
Jensen	149	11%	320	24%	10.01	90	7%
Johnston							
Kaiser							
Kane							
Karadayi	6	3%	14	7%		9	4%
Karlson							
Karmakar							
Katrancioglu							
Keech							

APPENDIX F: META-ANALYSIS TABLE CONTINUED

First Author	Number of cases of pneumonia	Percent of cases of pneumonia	Number of patients receiving mech ventilation	Percent of patients receiving mech ventilation	Mean duration of ventilation	Number of mortalities	Percent of mortalities
Kerr-Valentic							
Kessel						344	5%
Khandelwal							
Kieninger						5	3%
Kim							
Kim							
Labbe							
Lederer						19	100%
Lee						240	7%
Lien			26	0%		827	4%
Livingston	63	16%				22	6%
Love							
Lu	4	1%				6	2%
Luchette			14	74%			
Mackersie	0	0%					
Majercik	5	3%	21	14%			
Marasco	28	61%			7	1	2%
Marasco						41	10%
Matos	28	61%				34	74%
Matshes						5	100%
Maxwell							
Mayberry			5	50%			
Mayberry							
McKendy	108	8%			5.9	54	4%
Mohta	3	10%				0	0%
Nakae							
Nickerson							
Nirula			43	72%	8.85		
Oncel							
Osinowo							
Paik							
Park							
Pulley							
Sahr						14	9%
Sajjan							
Shackford			31	74%	11.8	6	14%
Shackford	9	25%	21	58%	4.9	3	8%
Shanti							
Sharma						97	12%
Shinohara							
Short							
Shulzhenko	3818	6%	10570	16%	8.6	4761	7%
Shweiki							
Sirmali	23	4%				31	6%
Solak							
Solberg	3	19%			0.792		
Stawicki					3.85	3928	14%
Szucs-Farkas							
Tanaka	19	51%	37	100%	14.65		
Tarng					6.42		
Taylor					4.8		
Testerman					1.7	7	2%
Trinkle	17	59%	22	76%	15	4	14%
Truitt			1	3%			
Truitt			2	2%			
Turk							
Ullman			10	36%			
Van Staa							
Velmahos	28	31%			16	12	13%
Vinther							
Waqar	16	19%				3	4%
Whitson	1445	4%					
Wilson							
Wisner	45	15%				40	13%
Worthley							
Wu	7	11%					
Wu	22	13%			6.8	5	3%
Wuermser							
Yeh						0	
Ziegler						84	12%