

BMJ Open Risk of pneumonia in patients with isolated minor rib fractures: a nationwide cohort study

Sai-Wai Ho,^{1,2,3} Ying-Hock Teng,^{2,3} Shun-Fa Yang,^{1,4} Han-Wei Yeh,⁵ Yu-Hsun Wang,⁴ Ming-Chih Chou,^{1,6} Chao-Bin Yeh^{2,3}

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SW-H and YH-T contributed equally.

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For numbered affiliations see end of article.

Correspondence to
Dr Chao-Bin Yeh;
sky5ff@gmail.com

ABSTRACT

Objectives: Isolated minor rib fractures (IMRFs) after blunt chest traumas are commonly observed in emergency departments. However, the relationship between IMRFs and subsequent pneumonia remains controversial. This nationwide cohort study investigated the association between IMRFs and the risk of pneumonia in patients with blunt chest traumas.

Design: Nationwide population-based cohort study.

Setting: Patients with IMRFs were identified between 2010 and 2011 from the Taiwan National Health Insurance Research Database.

Participants: Non-traumatic patients were matched through 1:8 propensity-score matching according to age, sex, and comorbidities (namely diabetes, hypertension, cardiovascular disease, asthma and chronic obstructive pulmonary disease (COPD)) with the comparison cohort. We estimated the adjusted HRs (aHRs) by using the Cox proportional hazard model. A total of 709 patients with IMRFs and 5672 non-traumatic patients were included.

Main outcome measure: The primary end point was the occurrence of pneumonia within 30 days.

Results: The incidence of pneumonia following IMRFs was 1.6% (11/709). The aHR for the risk of pneumonia after IMRFs was 8.94 (95% CI=3.79 to 21.09, $p<0.001$). Furthermore, old age (≥ 65 years; aHR=5.60, 95% CI 1.97 to 15.89, $p<0.001$) and COPD (aHR=5.41, 95% CI 1.02 to 3.59, $p<0.001$) were risk factors for pneumonia following IMRFs. In the IMRF group, presence of single or two isolated rib fractures was associated with an increased risk of pneumonia with aHRs of 3.97 (95% CI 1.09 to 14.44, $p<0.001$) and 17.13 (95% CI 6.66 to 44.04, $p<0.001$), respectively.

Conclusions: Although the incidence of pneumonia following IMRFs is low, patients with two isolated rib fractures were particularly susceptible to pneumonia. Physicians should focus on this complication, particularly in elderly patients and those with COPD.

INTRODUCTION

Pneumonia is an inflammatory process of the alveolar regions of the lung, which typically occurs because of microbial infections.^{1,2} The incidence of pneumonia ranged from 1.5 to

Strengths and limitations of this study

- The strength of this cohort study was the use of the Longitudinal Health Insurance Database 2010, which includes the nationwide data of 1 million insureds randomly selected from the 2010 Registry of Beneficiaries. Taiwan's National Health Insurance system, established in 1995, covers the medical expenses of ~98% of the Taiwanese population, providing accurate data of medical conditions in Taiwan.
- We obtained the number of rib fractures experienced by the patients from the data sets; however, information on the type of rib fractures was not obtained. Fractures of the first 3 ribs indicated a high-energy injury that may lead to increased complications.
- The National Health Insurance Research Database (NHIRD) does not provide detailed clinical parameters, such as the trauma mechanisms, injury severity score, abbreviated injury scale and laboratory data of the patients. Injury severity was one of the factors contributing to the risk of pneumonia in patients with multiple rib fractures.

14 cases per 1000 person-years and was the second major cause of deaths and years of life lost in 2013.^{3–5} Microorganisms that colonise the oropharynx and nasopharynx, including bacteria, virus, fungi and protozoa, are a common aetiology of pneumonia. Aspiration of the contaminated secretions causing pneumonia is common in trauma populations.⁶

Chest traumas account for ~796 000 emergency department (ED) visits annually in the USA.⁷ In Taiwan, chest traumas caused 18 856 hospitalisations during 2002–2004.⁸ Rib fractures are common in 7%–40% of all trauma cases, and 10% of the patients with traumatic rib fractures require hospitalisation.⁹ Furthermore, delayed pneumonia complications were common after multiple rib fractures.¹⁰ However, a low risk of delayed pneumonia was reported in patients with minor thoracic injuries.¹¹

Minor thoracic injury, which is defined by the presence of chest abrasion, chest contusion, or single or two isolated minor rib fractures (IMRFs), accounts for up to 42% of ED visits for blunt chest traumas.^{12–13} Most patients were directly discharged from ED after primary management. However, complications such as delayed pneumothorax, haemothorax, pneumonia and considerable functional limitations have been reported.^{11–16} Among all types of minor thoracic injuries, IMRFs after chest traumas are commonly observed in EDs; however, different ED settings have different disposition practices.¹⁷ IMRFs can cause considerable pain, impairing the coughing function and secretion clearance and leading to atelectasis and subsequent pneumonia.¹⁸ However, studies exploring the relationship between IMRFs and subsequent pneumonia have been limited to small sample sizes.^{11–17–19–20} This relationship is clinically relevant because delayed pneumonia after rib fractures has been strongly associated with mortality.²¹

MATERIALS AND METHODS

Data sources

A retrospective cohort population-based study was conducted using the registration and claims data sets from 2009 to 2011 obtained from the Longitudinal Health Insurance Database 2010 (LHID2010), which is a subset of the National Health Insurance Research Database (NHIRD) managed by the Taiwan National Health Research Institutes. Taiwan's National Health Insurance (NHI) system, established in 1995, covers the medical expenses of ~98% of Taiwan's residents (23 million); thus, it is one of the world's largest population-based data sets. The LHID2010 has a longitudinal design, containing all ambulatory and inpatient claims data, including disease diagnosis codes, drug prescriptions, diagnostic examinations and interventions, of 1 million beneficiaries (from 23 million) randomly sampled from the 2010 Registry of Beneficiaries of the NHIRD. In this study, the disease diagnosis codes were derived from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). The disease diagnosis coding is highly reliable because all insurance claims are scrutinised by medical reimbursement specialists and peer reviewers.

Study sample size and settings

All patients aged ≥ 18 years with blunt chest traumas between 1 January 2010 and 31 December 2011 were identified. Chest trauma was defined according to ICD-9-CM 807.0, 807.2, 807.4, 810.0, 811.0, 860.0, 860.2, 860.4, 861.21, 861.22, 862.2 and 862.8. First, we excluded patients aged < 18 years and those with a history of any traumas in the past 1 year (ICD-9-CM 800–897). Subsequently, we excluded patients diagnosed as having open chest trauma, traumatic pneumothorax and haemothorax (ICD-9-CM 860.1, 860.3, 860.5, 861.1, 861.3, 807.1 and 807.3) during the study period because these

types of pulmonary injuries can lead to subsequent pneumonia. Furthermore, patients with a history of pneumonia before chest traumas were excluded. IMRFs are defined as single or two rib fractures (ICD-9-CM 807.01 and 807.02) without other associated injuries.¹¹ In addition, data on diagnostic tests, such as chest X-ray (XR; order codes: 32001C, 32002C and 32003C) and CT; order codes: 33066B, 33070B, 33071B, and 33072B), were also obtained. Logistic regression analysis was conducted after propensity score matching for directly calculating the probability values of each pair of cases. The similarities between the probability values of the IMRF and control groups were determined. The optimal ratio from the analysis of variable multiple pairing was 1:8. Therefore, a propensity score matching (1:8) was performed for the control group according to age, sex, diabetes mellitus (ICD-9-CM 250), hypertension (ICD-9-CM 401–405), cardiovascular disease (ICD-9-CM 410–414), asthma (ICD-9-CM 493) and chronic obstructive pulmonary disease (COPD; ICD-9-CM 491, 492, 494 and 496). For determining the occurrence of any type of pneumonia, our study end points were pneumonia diagnosis (ICD-9-CM 481, 482.xx, 483.xx, 485 and 486), withdrawal from the NHI programme or 31 December 2011, whichever occurred first within 30 days of follow-up. **Figure 1** illustrates our study framework. This study was approved by the Institutional Review Board of the Chung Shan Medical University Hospital (CS2–15061). All personal data in the secondary files were de-identified before analysis; therefore, the review board waived the requirement to obtain written informed consent from the patients.

Statistical analysis

Categorical variables are presented as counts and percentages and were compared using the χ^2 test where appropriate. Continuous data are presented as the mean \pm SD and were compared using the independent t test. The Cox proportional hazard model was used for estimating the adjusted HR (aHR) for pneumonia. In addition, we adjusted for the potential confounding factors increasing the risk of pneumonia, namely age, sex, diabetes mellitus, hypertension, cardiovascular disease, asthma and COPD. Statistical analysis was performed using SPSS V.18.0 (SPSS, Chicago, Illinois, USA). $p < 0.05$ indicated statistical significance. The occurrence of pneumonia was assessed through Kaplan-Meier analysis, and significance was evaluated on the basis of the log-rank test.

RESULTS

After excluding patients aged < 18 years and patients who experienced traumas in the past 1 year, only 3602 patients with chest traumas were included. After matching, a total of 709 patients with IMRFs and 5672 non-traumatic patients were selected for final analysis (**figure 1**). Furthermore, 207 patients (29.2%)

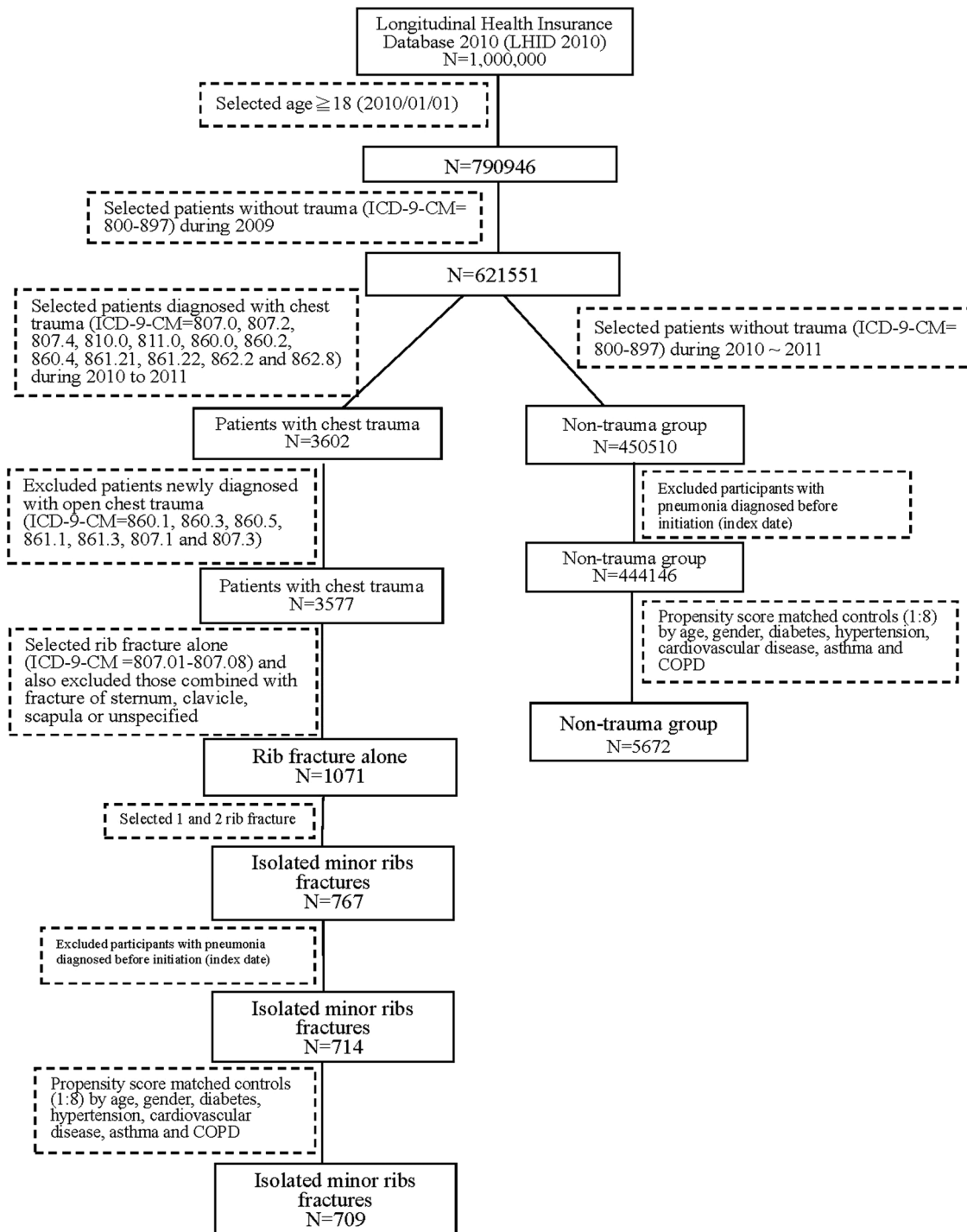


Figure 1 Flow chart for selecting patients with isolated minor rib fractures. COPD, chronic obstructive pulmonary disease.

diagnosed as having IMRFs were admitted to hospitals. [Table 1](#) presents the baseline demographics and comorbidities of the IMRF and control groups. After matching, the baseline demographics and comorbidities of the two groups did not vary significantly.

The incidence of pneumonia after IMRFs was 1.6% (11/709). More than 99% and 9% of the patients underwent only chest XR examination and both chest XR and CT examinations, respectively. The patients with IMRFs were at an increased risk of subsequent

pneumonia within 30 days. The aHR for pneumonia was 8.94 (95% CI 3.79 to 21.09, $p < 0.001$) after adjustment for age, sex and comorbidities. Moreover, old age (≥ 65 years; aHR=5.60, 95% CI 1.97 to 15.89, $p < 0.001$) and COPD (aHR=5.41, 95% CI 1.02 to 3.59, $p < 0.001$) were risk factors for pneumonia ([table 2](#)). [Table 3](#) demonstrates the risk stratification of pneumonia in the IMRF group; 476 and 233 patients had single and two isolated rib fractures, respectively. The aHRs of pneumonia in isolated single or two rib

Table 1 Demographic data of study population

	Unmatched				Matched					
	IMRF N=714		Non-traumatic patients N=444 146		n	IMRF N=709		Non-traumatic patients N=5672		p Value
	n	Per cent	n	Per cent		Per cent	p Value	n	Per cent	
Age on index date (years)					<0.001**					0.258
18–39	131	18.3	209 958	47.3		131	18.5	942	16.6	
40–64	377	52.8	186 801	42.1		377	53.2	2977	52.5	
≥65	206	28.9	47 387	10.7		201	28.3	1753	30.9	
Mean±SD	55.7±16.1		43.2±16.0		<0.001**	55.4±15.9		56.1±15.6		0.316
Age on index date (years)					<0.001**					0.164
<65	508	71.1	396 759	89.3		508	71.7	3919	69.1	
≥65	206	28.9	47 387	10.7		201	28.3	1753	30.9	
Mean±SD	55.7±16.1		43.2±16.0		<0.001**	55.4±15.9		56.1±15.6		0.316
Gender					<0.001**					0.711
Female	279	39.1	230 131	51.8		277	39.1	2257	39.8	
Male	435	60.9	214 015	48.2		432	60.9	3415	60.2	
Diabetes	105	14.7	26 566	6.0	<0.001**	104	14.7	822	14.5	0.900
Hypertension	198	27.7	57 382	12.9	<0.001**	194	27.4	1590	28.0	0.708
Cardiovascular disease	62	8.7	15 161	3.4	<0.001**	58	8.2	462	8.1	0.974
Asthma	31	4.3	632	0.1	<0.001**	30	4.2	240	4.2	1
COPD	45	6.3	9125	2.1	<0.001**	43	6.1	322	5.7	0.675

*p<0.05, **p<0.01.

COPD, chronic obstructive pulmonary disease; IMRF, isolated minor ribs fractures.

Table 2 Cox proportional HR of pneumonia between patients with IMRF (N=709) and non-traumatic patients (N=5672)

	Number of participants	Number of pneumonia event	Crude HR	95% CI		Adjusted HR	95% CI	
				Lower	Upper		Lower	Upper
Group								
Non-traumatic patients	5672	10	1			1		
IMRF	709	11	8.86**	3.76	20.86	8.94**	3.79	21.09
Age on index date (years)								
<65	4427	6	1			1		
≥65	1954	15	5.68**	2.20	14.64	5.60**	1.97	15.89
Gender								
Female	2534	5	1			1		
Male	3847	16	2.11	0.77	5.76	2.35	0.85	6.55
Diabetes	926	3	0.98	0.29	3.33	0.57	0.16	2.04
Hypertension	1784	8	1.59	0.66	3.83	0.87	0.32	2.37
Cardiovascular disease	520	2	1.19	0.28	5.09	0.94	0.20	4.31
Asthma	270	1	1.13	0.15	8.45	0.32	0.04	2.59
COPD	365	7	8.29**	3.35	20.54	5.41**	2.01	14.55

*p<0.05, **p<0.01.

COPD, chronic obstructive pulmonary disease; IMRF, isolated minor ribs fractures.

fractures were 3.97 (95% CI 1.09 to 14.44, p<0.001) and 17.13 (95% CI 6.66 to 44.04, p<0.001), respectively.

Table 4 presents the characteristics of patients with IMRFs who were and were not hospitalised. Patients hospitalised for IMRFs had significant underlying comorbidities, such as hypertension (p=0.022) and cardiovascular disease (p=0.015). However, the risk of delayed pneumonia did not significantly differ in

patients admitted or not admitted to hospitals (p=0.313).

Figure 2 illustrates the time elapsed from IMRFs to subsequent pneumonia. More than 72.7% (8/11) of the patients developed pneumonia within 2 weeks after IMRFs. Figure 3 depicts the Kaplan-Meier curves for the occurrence of pneumonia in the non-traumatic patients and patients with IMRFs. The cumulative incidence of pneumonia was higher in patients with IMRFs than in

Table 3 Cox proportional HR of pneumonia in IMRF subgroups

Group	Number of participants	Number of pneumonia event	Crude HR	95% CI		Adjusted HR†	95% CI	
				Lower	Upper		Lower	Upper
Non-traumatic patients	5672	10	1			1		
Number of IMRF=1	476	3	3.58	0.99	13.02	3.97*	1.09	14.44
Number of IMRF=2	233	8	19.75**	7.80	50.05	17.13**	6.66	44.04
IMRF (N=709)								
1	476	3	1			1		
2	233	8	5.51*	1.46	20.76	4.76*	1.24	18.23

*p<0.05, **p<0.01.

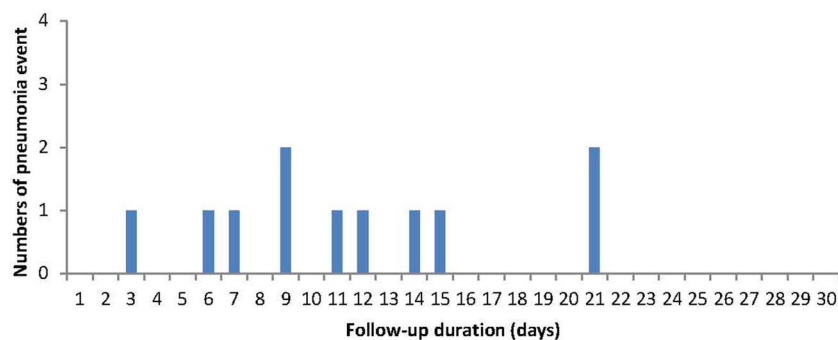
†Adjusted for age, gender, diabetes, hypertension, cardiovascular disease, asthma and COPD. COPD, chronic obstructive pulmonary disease; IMRF, isolated minor rib fractures.

Table 4 Analysis of patients with IMRF with and without hospitalisation

	IMRF with hospitalisation N=207		IMRF without hospitalisation N=502		p Value
	n	Per cent	n	Per cent	
Age on index date					
Mean±SD	56.7±16.2		54.9±15.7		0.176
Gender					0.012*
Female	66	31.9	211	42.0	
Male	141	68.1	291	58.0	
Comorbidity					
Diabetes	38	18.4	66	13.1	0.075
Hypertension	69	33.3	125	24.9	0.022*
Cardiovascular disease	25	12.1	33	6.6	0.015*
Asthma	12	5.8	18	3.6	0.184
COPD	17	8.2	26	5.2	0.124
Pneumonia	5	2.4	6	1.2	0.313

*p<0.05, **p<0.01.

COPD, chronic obstructive pulmonary disease; IMRF, isolated minor rib fractures.

Figure 2 Time elapsed between rib fractures and development of pneumonia. IMRF, isolated minor rib fractures.

non-traumatic patients throughout the 30-day follow-up period. The log-rank test findings revealed significant differences ($p<0.001$).

DISCUSSION

In this nationwide population-based study, the incidence of pneumonia following IMRFs was 1.6%. Although this

low incidence is similar to that reported in Canada (0.6%),¹¹ our study demonstrated a high aHR of 8.94 (95% CI 3.79 to 21.09) for pneumonia in patients with IMRFs. Furthermore, old age (≥ 65 years; aHR=5.60 (95% CI 1.97 to 15.89)) and COPD (aHR=5.41, 95% CI 1.02 to 3.59) were risk factors for pneumonia after IMRFs.

The possible pathophysiology for developing pneumonia after IMRFs is discussed herein. First, pain caused by

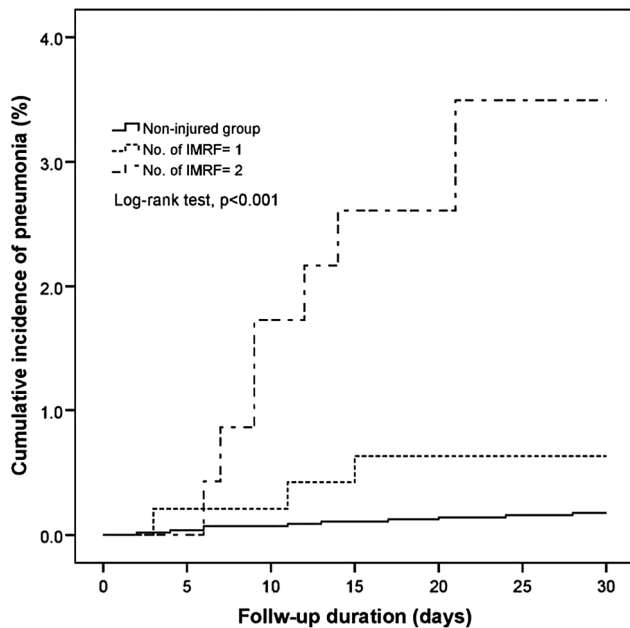


Figure 3 Kaplan-Meier curves of the cumulative incidence of pneumonia in patients with isolated rib fractures and non-traumatic patients.

IMRFs can impair the coughing function and secretion clearance, which would reduce respiratory effort and lead to atelectasis and subsequent pneumonia. Elderly patients are highly susceptible to IMRFs because of inadequate physiological reserves and poor functional residual capacity.²² Pre-existing comorbidities and low immunity and frailty are the possible contributing factors to infection in the elderly patients. Bulger *et al* demonstrated that of the 464 patients with rib fractures, pneumonia occurred in 31% and 17% elderly and young patients, respectively. Furthermore, the incidence of pneumonia reached 51% in elderly patients with more than six rib fractures.²³ Pre-existing comorbidities, such as congestive heart failure, ischaemic heart disease, COPD, diabetes and cirrhosis have been reported as well-known contributing factors for morbidity in elderly patients.^{22–24} Therefore, aggressive treatment of pain is crucial for rib fracture management in elderly patients. Adequate analgesia and breathing exercises have reduced the number of ventilator days and pneumonia incidence rates.^{25–27}

Second, rib fractures are typically accompanied by pulmonary contusions after blunt chest traumas.^{28–29} Furthermore, chest contusion was reported as the most common occult injury during chest traumas.³⁰ However, the incidence of pulmonary contusions, which were verified using CT, in patients with IMRFs was merely 0.6% (4/704) in our study and none of these patients developed delayed pneumonia. The true incidence of pulmonary contusion may be underestimated because only 19.5% of the patients with IMRFs underwent CT examinations. Furthermore, pulmonary contusions were not observed in the 11 patients who developed pneumonia in the IMRF group.

A systematic review and meta-analysis reported that pre-existing comorbidities, particularly cardiopulmonary disease and pneumonia, were risk factors for mortality following blunt chest traumas.³¹ Our study observed that only patients with pre-existing COPD without asthma or cardiovascular disease were at an increased risk of subsequent pneumonia after IMRFs. Patients with rib fractures having underlying lung diseases, such as COPD or asthma, were more susceptible to lung function impairment.³² Furthermore, patients with rib fractures having a vital capacity of <30% were at an increased risk of pulmonary complications.³³ Moreover, lung function impairment can occur because of rib fractures and underlying pulmonary disease. In this study, we demonstrated that only COPD was associated with subsequent pneumonia after IMRFs.

The strength of this cohort study was the use of the nationwide database, LHID2010, including data of 1 million insureds randomly selected from the 2010 Registry of Beneficiaries. Taiwan's NHI system, established in 1995, covers the medical expenses of ~98% of the Taiwanese population, thus providing accurate data of medical conditions in Taiwan. However, our study had several limitations. First, we could only obtain the number of patients with rib fractures experienced from the data sets and information on the type of rib fractures was not obtained. Fractures of the first 3 ribs indicated a high-energy injury that may lead to increased complications. However, Ziegler *et al*⁹ reported that the number of rib fractures and incidence of pulmonary complications, including pneumothorax, haemothorax, lung contusions and pneumonia, were not correlated. Second, the NHIRD does not provide the mechanism of injury or detailed clinical parameters, such as the injury severity score, abbreviated injury scale and laboratory data of the patients. Rib fractures sustained from high-energy traumas have a higher incidence of pulmonary contusions and other pulmonary traumas, which potentially pose a greater risk of pneumonia, than those sustained from low-energy traumas. Moreover, injury severity was reported to be a risk factor for pneumonia in patients with multiple rib fractures.²¹ Since we selected only patients with isolated single or two rib fractures, the trauma scores were low. Third, only 19% of the patients with IMRFs were diagnosed on the basis of both chest X-ray and CT examinations. Routine chest CT is not necessary in minor chest injury. However, up to 50% of rib fractures may be missed on a standard chest radiograph; therefore, the incidence of pneumonia after IMRFs might be overestimated in our study.²² Fourth, propensity score matching used probability values for pairing the IMRF and control groups. Only the independent variables in pairing between the two groups were considered for reducing the existing differences; however, other independent variables that may affect the final results were not considered. Therefore, the results after pairing may exhibit significant differences between the groups. Moreover, the pairing method is suitable for

large sample studies, and small sample studies with inadequate sample sizes may lead to selection bias. Fifth, 29.2% patients were admitted to hospitals after being diagnosed with IMRFs in our study. Different countries and ED settings have different disposition practices; therefore, the present findings should be cautiously interpreted and generalised to other countries. Finally, the shortcomings of the retrospective methodology used in this study should be considered.

CONCLUSION

The incidence of pneumonia following IMRFs was low. Moreover, patients with two isolated rib fractures were particularly susceptible to pneumonia. Physicians should focus on this complication, particularly in elderly patients and those with COPD. We recommend that patients with single or two rib fractures should receive attentive follow-up care.

Author affiliations

¹Institute of Medicine, Chung Shan Medical University, Taichung, Taiwan

²Department of Emergency Medicine, School of Medicine, Chung Shan Medical University, Taichung, Taiwan

³Department of Emergency Medicine, Chung Shan Medical University Hospital, Taichung, Taiwan

⁴Department of Medical Research, Chung Shan Medical University Hospital, Taichung, Taiwan

⁵School of Medicine, Chang Gung University, Taoyuan City, Taiwan

⁶Department of Surgery, Chung Shan Medical University Hospital, Taichung, Taiwan

Contributors S-WH and C-BY conceived and designed the experiments. S-FY, Y-HT and Y-HW analysed the data. H-WY and M-CC contributed reagents/materials/analysis tools. S-WH and C-BY wrote the paper.

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Competing interests None declared.

Patient consent Obtained.

Ethics approval Institutional Review Board of Chung Shan Medical University Hospital.

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