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Do simple beside lung function tests predict morbidity after rib fractures?

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ABSTRACT

Background: We evaluated if incentive spirometry volume (ISV) and peak expiratory flow rate (PEFR) could predict acute respiratory failure (ARF) in patients with rib fractures.
Methods: Normotensive, co-operative patients were enrolled prospectively. ISV and PEFR were measured on admission, at 24 h and at 48 h by taking the best of three readings each time. The primary outcome, ARF, was defined as requiring invasive or noninvasive positive pressure ventilation.
Results: 99 patients were enrolled (median age, 77 years). ARF occurred in 9%. Of the lung function tests, only a low median ISV at admission was associated with ARF (500 ml vs 1250 ml, $p = 0.04$). Three of 69 patients with ISV of ≥1000 ml versus six of 30 with ISV <1000 ml developed ARF ($p = 0.01$). Other significant factors were: number of rib fractures, tube thoracostomy, any lower-third rib fracture, flail segment.
Conclusion: PEFR did not predict ARF. Admission ISV may have value in predicting ARF.

1. Background

Risk factors for complications following rib fractures have been well studied. They include age, number and the anatomic characteristics of the rib fractures.[1–3] The role of lung function testing in predicting complications after rib fractures is less well established. A small study[4] previously found no correlation of vital capacity with pulmonary complications but a recent larger retrospective study found otherwise.[5]

Incentive spirometry is considered to be a component of bronchial hygiene therapy and is widely used in the post-operative setting as well as acute trauma with the aim of minimizing atelectasis.[6] While the rationale for its use is therapeutic, very few studies have studied its role as a predictive tool for pulmonary complications.[7] Another parameter that is used widely to diagnose and manage asthma is the peak expiratory flow rate (PEFR), measured by a hand-held peak flow meter. Its use as a prognostic tool in patients after rib fractures similarly has not been studied. We therefore aimed to evaluate if incentive spirometry volume (ISV) and PEFR could predict respiratory failure in patients with rib fractures.

2. Methods

This was a prospective study approved by the hospital Institutional Review Board and carried out from January to September 2015. Patients with rib fracture(s) after blunt trauma and who were 18 years and older were screened and enrolled if they met the following criteria: requirement for inpatient admission, Glasgow Coma Scale Score (GCS) ≥14, not anticipated to require endotracheal intubation for thoracic, neurologic, or abdominal procedures during the first 48 h after admission, deemed able to co-operate with lung function testing and give informed consent. Patients who required invasive or non-invasive mechanical ventilation, who were hypotensive (<100 mmHg) or who manifested obvious signs of shock in the Emergency Department (ED), and where the time of injury exceeded 48 h prior to presentation were excluded.

The management of rib fractures was in accordance with our institutional practice incorporating a nursing –driven early mobilization protocol and pain management guidelines utilized by the

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trauma surgery service. The Wong-Baker FACES scale, an ordinal scale of 0–10 (wongbakerfaces.org), was used to assess pain. Non-steroidal anti-inflammatory drugs and acetaminophen were generally used for mild pain (pain score 0–3), oral opioids for moderate pain (pain score 4–7) and intravenous opioids used for severe (pain score 8–10) or breakthrough pain. If patients after admission were found to have inadequate pain control despite the above regimen, thoracic epidural analgesia was considered if there were no contraindications. For patients with displaced rib fractures or flail chest who failed to improve or deteriorated clinically, operative rib fixation was considered based on the discretion of the trauma attending.

Lung function testing was performed and recorded by a member of the trauma service (advanced practitioners, surgical resident or trauma attending). Respiratory therapists were not used because these tests could be performed by patients with minimal assistance from a trauma service provider.

ISV was measured using a hand-held device (Voldyne 2500, Hudson RCI), based on the American Association of Respiratory Care (AARC) clinical practice guideline.[6] The best of three measurements was recorded as the ISV. The Strive Dual Zone Peak Flow Meter (Monaghan Medical Corporation) was used to obtain PEFR measurements based on the technique recommended by the American Lung Association (ALA) for patients with asthma (http://www.lung.org/lung-health-and-diseases/lung-disease-lookup/asthma/living-with-asthma/managing-asthma/measuring-your-peak-flow-rate/). The best of three measurements was recorded as the PEFR. Three sets of ISV and PEFR were recorded at three separate times: ISV1, PEFR1 (at admission), ISV2, PEFR2 (at 24 h), and ISV3, PEFR3 (at 48 h).

Patients were prospectively followed for 30 days after injury. Other variables collected included age, body mass index, history of active smoking, pre-existing diagnosis of chronic obstructive pulmonary disease (COPD), bronchodilator use within the past 30 days, total number and location of rib fractures, presence or absence of a flail segment (defined as three or more segmental rib fractures), pulse oximetry oxygen saturation on room air on admission, and admission pain scale rating. Fracture location was also divided into thirds (upper third, 1st to the 4th rib; middle third, 5th to the 8th ribs; lower third, 9th to the 12th rib). The primary outcome for this study was acute respiratory failure (ARF), defined as the need for invasive or non-invasive mechanical ventilation within 30 days after injury. As there was a lack of published data on outcomes, a sample size could not be determined *apriori*.

Univariable analysis with the chi-squared test, Fisher's exact test, or Mann Whitney *U* test were used as appropriate to determine associations with the primary outcome, with a p value of 0.05 indicating statistical significance. Significant factors by univariable analysis were entered into a logistic regression model to evaluate if there were independent risk factors associated with ARF. Statistical analysis was performed using Minitab 16 (State College, Pennsylvania, USA).

3. Results

Ninety-nine eligible patients were enrolled over the nine-month period. Characteristics of the sample are shown in Table 1. The majority of patients were 65 years and older (Table 1).

Due to patient discharges, achievement of the primary outcome and patient non-cooperation or refusal, ISV2, ISV3, PEFR2 and PEFR3 measurements could only be obtained in 81%, 64%, 78% and 60% of the initial study sample respectively.

ARF occurred in 9 of 99 (9%, 95% confidence interval [C.I.] 4.2%–16.6%). Four of the 9 patients required endotracheal intubation while the others needed non-invasive positive pressure ventilation.

Table 1
Characteristics of the study sample ($n = 99$).

Median age (years)[a]	77 (60–84)
Age ≥65 years	68%
Male gender	53%
Median body mass index[a]	27.7 (23.9–32.8)
Chronic obstructive pulmonary disease	17%
Active smoker	15%
Bronchodilator use in past month	17%
Median AIS- chest[a]	3 (3–3)
Median ISS[a]	10-(9–14)
Median total number of rib fractures per patient[a]	4 (3–6)
≥4 rib fractures	68%
Any upper third rib fractures	46%
Any middle third rib fractures	87%
Any lower third rib fractures	67%
Associated sternal fractures	6%
Flail segment	9%
Bilateral rib fractures	19%
Median pulse oximetry saturation at room air at admission[a]	95 (93–96)
Median pain scale rating at admission[a]	5 (3–8)
Median ISV1 (ml)[a]	1250 (750–1750)
ISV1 ≥ 1000 ml	57%
Medan ISV2 (ml)[a](n = 81)[b]	1250 (750–1750)
Median ISV3 (ml)[a] (n = 64)[b]	1250 (1000 –1700)
Median PEFR1 (L/sec)[a]	173 (110–242.5)
Median PEFR2 (L/sec)[a] (n = 78)[b]	205 (150–250)
Median PEFR3 (L/sec)[a] (n = 60)[b]	200 (100–240)
Median PEFR1/predicted PEFR[a]	0.36 (0.23–0.47)
Median PEFR2/predicted PEFR[a]	0.39 (0.32–0.54)
Median PEFR3/predicted PEFR[a]	0.41 (0.29–0.50)
Tube thoracostomy	17%
Epidural analgesia	1%
Operative rib fixation	1%

Abbreviations: AIS: Abbreviated Injury Score; ISS: Injury Severity Score; PEFR: peak expiratory flow rate; PEFR1: peak expiratory flow rate at admission; PEFR2: peak expiratory flow rate at 24 h; PEFR3: peak expiratory flow rate at 48 h; ISV: incentive spirometry volume; ISV1: incentive spirometry volume at admission; ISV2: incentive spirometry volume at 24 h; ISV3: incentive spirometry volume at 48 h.
[a] Expressed with interquartile range.
[b] Not the original sample size due to achievement of endpoint, patient discharge from hospital or patient inability or refusal to perform measurements.

One of the patients that required non-invasive positive pressure ventilation had surgical rib stabilization. By univariable analysis, significant variables associated with ARF were ISV1, number of rib fractures, presence of a flail segment, presence of any lower third fractures, AIS- chest, and the need for tube thoracostomy (Table 2). When ISV1 was <1000 ml, 6 of 30 (20%) had ARF as compared to 3 of 69 (4%) when it was ≥1000 ml. None of the PEFR measurements were predictive of ARF. Thirty-day mortality was 4/99 (4%) of which two were a direct consequence of ARF.

The relationships between ISV on admission (ISV1) with respect to the admission pain score, total number of rib fractures, presence of bilateral fractures, and presence of a flail segment respectively were further explored. There was no meaningful correlation between ISV1 and pain score (Pearson coefficient $= -0.18$) or the total number of rib fractures (Pearson coefficient $= -0.02$). In addition, there was no association between ISV1 and the presence of bilateral rib fractures ($p = 0.4$) or flail segment ($p = 0.3$).

Binary logistic regression was performed entering all significant variables with p value of ≤0.05 into the model to evaluate factors predicting ARF. After model fitting the final model consisted of the following: total number of rib fractures, tube thoracostomy, ISV≥1000 ml. Need for tube thoracostomy (odds ratio [OR] 12.2 with 95% confidence interval [CI] 2.2–67) and the total number of rib fractures (OR 1.3, 95% CI 1.3–1.7) were significant predictors at the 95% significance level, while ISV1 of ≥1000 ml (OR 0.19, 95% CI 0.03–1.01, $p = 0.051$) was not. The model had acceptable goodness