

## Original Article

# Incentive spirometry to prevent pulmonary complications after chest trauma: a retrospective observational study

Hisashi Dote,<sup>1</sup>  Yohichiro Homma,<sup>2</sup>  Masaaki Sakuraya,<sup>3</sup> Hiraku Funakoshi,<sup>4</sup>   
Shigeru Tanaka,<sup>1</sup> and Takahiro Atsumi<sup>1</sup>

<sup>1</sup>Department of Emergency and Critical Care Medicine, <sup>2</sup>Department of General Internal Medicine, Seirei Hamamatsu General Hospital, Hamamatsu, <sup>3</sup>Division of Emergency and Critical Care Medicine, JA Hiroshima General Hospital, Hiroshima, and <sup>4</sup>Department of Emergency and Critical Care Medicine, Tokyo Bay Urayasu Ichikawa Medical Center, Urayasu, Japan

**Aim:** Pulmonary complications (PCs) are a major cause of poor prognosis in chest trauma. Evidence on the effectiveness of incentive spirometry (IS) in trauma is scarce. This study investigated the effectiveness of IS in preventing PCs in patients with chest trauma with rib fractures.

**Methods:** This retrospective observational study analyzed the data obtained from the electronic medical records of patients with chest trauma with rib fractures admitted between 2011 and 2019. We included patients 18 years of age or older with risk of worsening respiratory failure. Early IS was the primary exposure and PCs (pulmonary infection or respiratory failure requiring escalating oxygen therapy) were the primary outcomes. Secondary outcomes were length of hospital stay, duration of oxygenation therapy, and adverse events of IS. Logistic regression analysis with a propensity score was used.

**Results:** We extracted 514 patients from the electronic medical records; 299 patients were included. The early IS group had a higher proportion of hypoxemia at admission, opioid analgesia use, invasive positive pressure ventilation, and respiratory physiotherapy. The severity of trauma was higher in the early IS group. There was no significant difference in the occurrence of the PCs between groups (adjusted odds ratio 0.71; 95% confidence interval, 0.24–2.16). No statistical differences were seen in the secondary outcomes.

**Conclusion:** For patients with chest trauma with rib fractures at risk of worsening respiratory failure, IS early after injury did not reduce the rate of PCs. No adverse event of IS was observed and IS was shown to be safe.

**Key words:** Chest injury, incentive spirometry, pulmonary complication, rib fracture

## INTRODUCTION

CHEST TRAUMA ACCOUNTS for more than 15% of trauma cases visiting the emergency department.<sup>1</sup> The incidence of chest trauma with rib fractures is increasing, especially in older adults.<sup>2</sup> The mortality rate from chest trauma with rib fractures is estimated at approximately 10%,<sup>3</sup> and pulmonary complications (PCs) are a major cause of death.<sup>4</sup> Recent studies suggest that internal fixation of rib fractures and multimodal analgesia, including epidural anesthesia, are effective for preventing PCs.<sup>2</sup> Applying these procedures to all patients with chest trauma is impractical

because they are specialized and highly invasive techniques. Thus, the clinical management strategy for preventing PCs is a major clinical problem.

Incentive spirometry (IS) is a device that is used for respiratory physiotherapy; designed to encourage patients to achieve maximal inspiration by providing visual feedback, IS is minimally invasive and inexpensive. Bartlett *et al.* first reported that IS decreases postoperative PCs,<sup>5</sup> and there are many studies that have investigated the effect of IS, mainly in a perioperative situation.<sup>6</sup> Furthermore, IS is frequently used for trauma patients,<sup>7</sup> although few studies have examined its effectiveness in these populations.<sup>2</sup> We hypothesized that trauma patients often have more limitations with regard to the implementation of rehabilitative strategies than perioperative patients. Therefore, the importance of IS for preventing PCs might be greater in trauma patients. With due consideration to the feasibility and cost-effectiveness, IS could be a promising treatment option in patients with chest trauma with rib fractures.

**Corresponding:** Hisashi Dote MD, Department of Emergency and Critical Care Medicine, Seirei Hamamatsu General Hospital, Hamamatsu, Japan. E-mail: hisashi.dote@gmail.com.

Received 4 Sep, 2020; accepted 1 Dec, 2020

### Funding information

No funding information provided.

In this study, we aimed to verify the abovementioned hypothesis. Therefore, we investigate the efficacy of IS in preventing PCs in patients with chest trauma with rib fractures.

## MATERIALS AND METHODS

### Study settings

WE OBTAINED DATA from the electronic medical records of patients with chest trauma with rib fractures admitted to Seirei Hamamatsu General Hospital (Hamamatsu, Japan) between April 2011 and March 2019. Specific International Classification of Diseases, Tenth Revision (ICD-10) codes were referenced (S22.2: Fracture of sternum; S22.3: Fracture of rib; S22.4: Multiple fracture of ribs; S27.2: Traumatic hemopneumothorax; and S27.3: Other injuries of lung). Seirei Hamamatsu General Hospital is an urban tertiary acute care and teaching hospital with 750 beds that treats more than 20,000 emergency patients and has more than 200 inpatients admitted for trauma every year.

### Exposure variables

The patients were divided into two groups based on whether they did (early IS group) or did not (non-early IS group) receive IS early after the injury. Based on a previous study that showed that the onset of pneumonia after chest trauma is more common 3 days post-injury,<sup>4,8</sup> the primary exposure was specified as early IS (started within 3 days of hospitalization or within 3 days of withdrawal of mechanical ventilation). The cases in which mechanical ventilation was started later than 24 h after admission and IS was started after the withdrawal of mechanical ventilation were assigned to the non-early IS group. We used InspireX (Japan Medicalnext, Osaka, Japan) for IS. Whether the patients receive IS or not was determined from the physician's orders in the medical record. The start and discontinuation of IS and the frequency of its use were decided individually by the physician. In principle, physicians order the IS with the frequency (e.g., once in the morning, noon, and evening) and the number of inhalations (e.g., 10 or more times). Incentive spirometry was initiated after the nurse or physiotherapist explained its use to the patient and monitored its implementation as necessary.

### Inclusion and exclusion criteria

We included adult patients (age  $\geq 18$  years) with chest trauma with rib fractures who had at least one risk of

worsening respiratory failure (hypoxemia at admission, three or more rib fractures, history of chronic respiratory disease, and age  $\geq 65$  years) at the time of admission.<sup>4</sup> We excluded patients who did not have any rib fractures, and those with altered mental status (the inability to follow instructions to rehabilitative movements), facial injury, or respiratory muscle paralysis due to cervical spinal cord injury.<sup>9</sup> Moreover, we excluded patients who did not have data on chest computed tomography scanning.

The definition of the variables is as follows. Patients who had oxygen saturation (SpO<sub>2</sub>) less than 92% with room air or were given any supplemental oxygen therapy on admission were considered to have hypoxemia at admission. The number of rib fractures was ascertained from chest computed tomography images. Patients with a history of respiratory surgery, chronic obstructive pulmonary disease, or interstitial lung disease were considered to have a history of chronic respiratory disease.<sup>4,10</sup>

### Outcome measures

The primary outcome measure was PC, defined as pulmonary infection (cases in which antimicrobial treatment was initiated based on the diagnosis of pneumonia or pyothorax from the descriptions of medical records) or respiratory failure requiring the escalation of oxygen therapy (e.g., starting new oxygen therapy, or change from conventional oxygen therapy to high-flow therapy or mechanical ventilation). We included events that occurred after the fourth day of hospitalization, or at the end of mechanical ventilation if the mechanical ventilation was started within 24 h of admission. The secondary outcome measures were length of hospital stay, duration of oxygenation therapy, and adverse events of IS (e.g., exacerbation of pneumothorax or worsening of pain).<sup>11</sup> The above variables were determined from the patients' medical records.

### Other variables

We calculated the propensity score (PS) for each individual based on the following variables: age, sex, body mass index, history of chronic respiratory or cardiac disease, hypoxemia at admission, the Injury Severity Score,<sup>12</sup> Abbreviated Injury Scale (AIS) score<sup>12</sup> for the chest and face, use of mechanical ventilation (invasive and non-invasive positive pressure ventilation), use of opioid analgesia, the number of rib fractures, presence or absence of traumatic pneumothorax and flail chest, tube thoracostomy placement, surgical fixation of fractured ribs, smoking history, preadmission anticoagulation therapy, or respiratory physiotherapy by physiotherapists after admission. These variables were also

used in the linear regression analysis for the secondary outcomes.

### Statistical analysis

We used Fisher's exact test to compare the proportions of binary variables, and the Mann–Whitney *U*-test to compare the continuous variables. Statistical significance was defined as  $P < 0.05$ . We used a logistic regression model to generate the PS between the groups: early IS and non-early IS. We undertook a logistic regression analysis with PS included as a covariate to adjust for confounders about the primary outcome. The secondary outcomes (length of hospital stay and duration of oxygenation therapy) were validated using linear regression analysis. All statistical analyses were carried out by using EZR version 1.50 (Saitama Medical Center, Jichi Medical University, Saitama, Japan).<sup>13</sup>

## RESULTS

### Patient characteristics

**D**URING THE STUDY period, 514 patients were hospitalized for chest trauma, with or without trauma to other body parts. A total of 299 patients were included in the final analysis dataset after applying the inclusion and exclusion criteria (Fig. 1).

Patients' characteristics and outcomes are shown in Table 1. The early IS group had a higher proportion of patients with hypoxemia at admission, opioid analgesia use, invasive positive pressure ventilation, and respiratory physiotherapy. Moreover, the early IS groups had higher Injury Severity Score, and AIS score for the chest injury (Table 1). The duration of days from hospitalization to the start of IS in each group is shown in Figure 2.

### Primary and secondary outcomes

The primary outcomes are shown in Table 2. There was no significant difference in the occurrence of PCs between groups (adjusted odds ratio 0.71; 95% confidence interval [CI], 0.24–2.16). Similar results were obtained in examining the components of PCs (pulmonary infection or escalated oxygen therapy) separately.

There was no significant difference in the secondary outcomes by linear regression analysis, length of hospital stay (beta coefficients  $-1.29$ ; 95% CI,  $-7.78$  to  $5.19$ ), or duration of oxygenation therapy (beta coefficients  $-0.22$ ; 95% CI,  $-1.95$  to  $2.38$ ). No adverse events of IS (i.e., exacerbation of pneumothorax or worsening of pain) were reported in either group.

We undertook subgroup analyses that excluded cases with trauma of AIS 3 or greater in any regions other than the

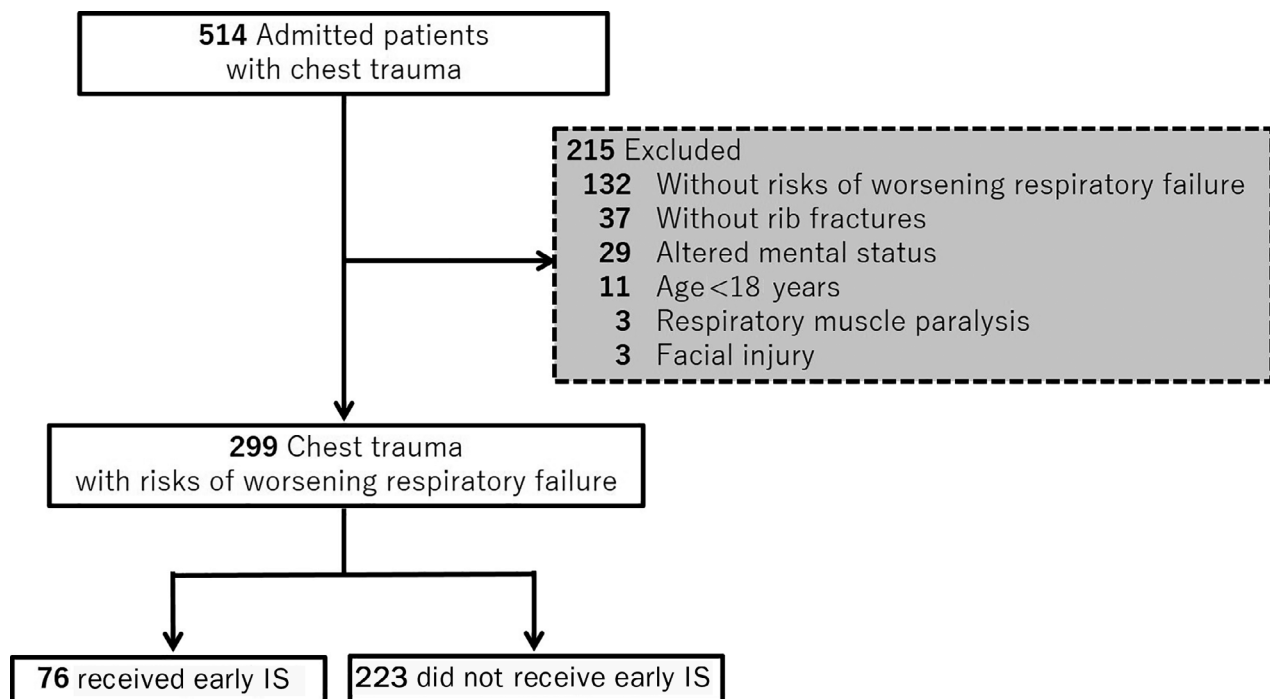


Fig. 1. Study inclusion flowchart. IS, incentive spirometry.

**Table 1.** Comparison of clinical characteristics and outcomes in patients with chest trauma who received early incentive spirometry (IS) and those who did not receive early IS

Characteristic	Early IS group <i>n</i> = 76	Non-early IS group <i>n</i> = 223	<i>P</i> -value
Age, years	66.0 (55.5, 78.3)	67.0 (52.5, 78.0)	0.7
Male gender	52 (68.4)	155 (69.5)	0.9
BMI, kg/m <sup>2</sup>	22.2 (19.7, 24.9)	21.8 (19.5, 23.3)	0.07
AIS (chest)	3.0 (3.0, 4.0)	3.0 (3.0, 3.0)	0.004
ISS	19.0 (11.8, 27.5)	13.0 (9.0, 18.0)	<0.001
Hypoxemia at admission	63 (82.9)	107 (48.0)	<0.001
Number of rib fractures	5.0 (3.0, 6.0)	4.0 (2.0, 6.0)	0.06
History of chronic respiratory disease	8 (10.5)	19 (8.5)	0.7
History of chronic cardiac disease	11 (14.5)	23 (10.3)	0.4
Smoking history	23 (30.3)	79 (35.4)	0.5
Anticoagulation therapy before admission	13 (17.1)	37 (16.7)	1
IPPV	17 (22.4)	15 (6.7)	<0.001
NPPV	5 (6.6)	7 (3.1)	0.2
Opioids used for analgesia	22 (28.9)	22 (9.9)	<0.001
Received IS during admission	76 (100.0)	14 (6.3)	<0.001
Surgical fixation of fractured ribs	0 (0.0)	0 (0.0)	1
Flail chest	0 (0.0)	2 (0.9)	1
Pneumothorax	25 (32.9)	87 (39.2)	0.3
Tube thoracostomy or thoracentesis	25 (32.9)	70 (31.4)	0.9
Respiratory physiotherapy	28 (36.8)	26 (11.7)	<0.001
Pulmonary complications	7 (9.2)	15 (6.7)	0.5
Pulmonary infection	6 (7.9)	13 (5.8)	0.6
Escalation of oxygen therapy	1 (1.3)	6 (2.7)	0.7
Hospital length of stay, days	22.5 (11.8, 41.0)	12.0 (7.0, 24.5)	<0.001
Duration of oxygenation therapy, days	4.5 (2.0, 10.0)	1.0 (0.0, 3.0)	<0.001
Adverse events of IS	0 (0.0)	0 (0.0)	1

Data are shown as *n* (%) or median (interquartile range).

AIS, Abbreviated Injury Scale; BMI, body mass index; IPPV, invasive positive pressure ventilation; ISS, injury severity score; NPPV, non-invasive positive pressure ventilation.

chest, and excluded patients receiving mechanical ventilation, but the results were the same.

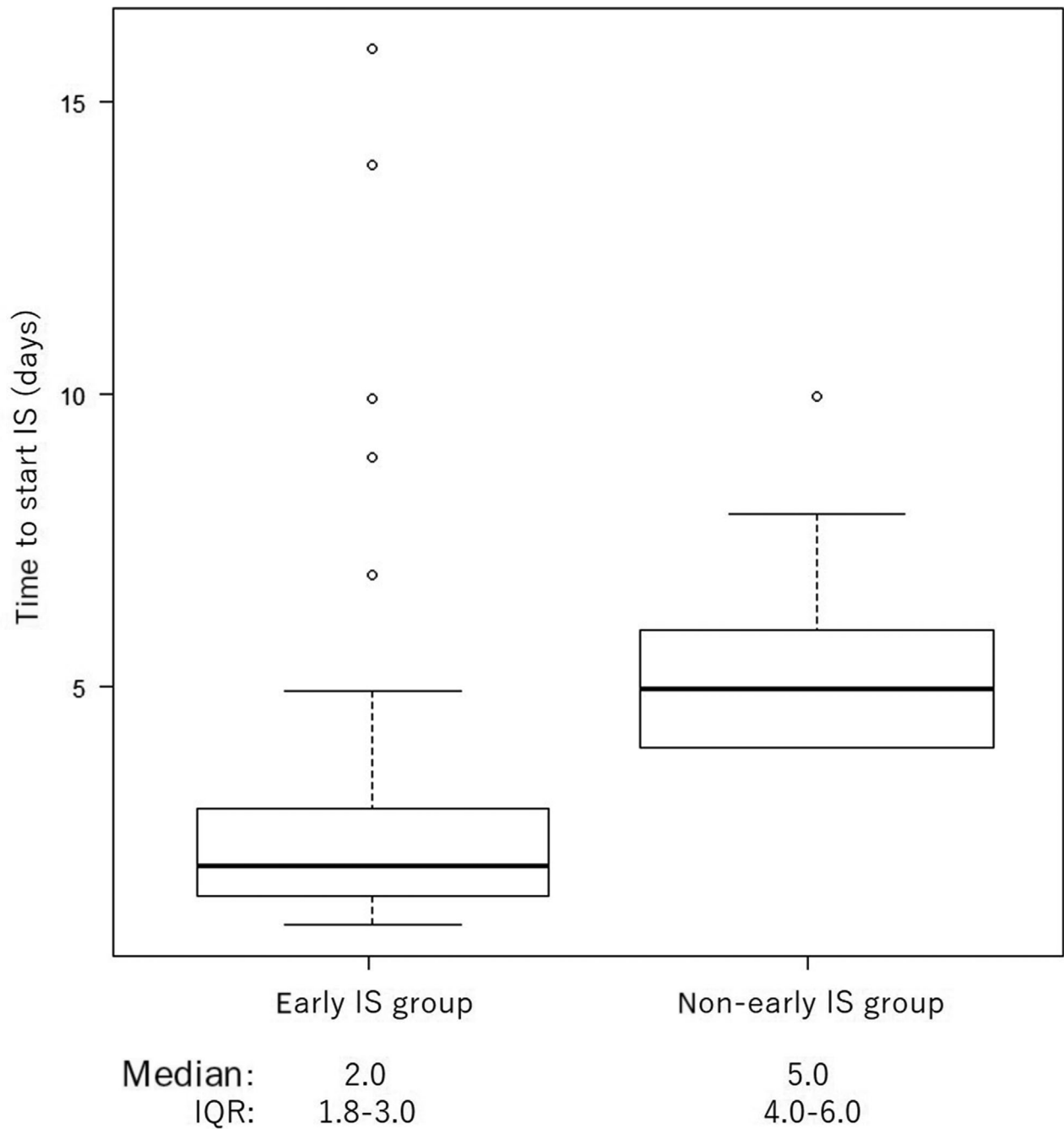
## DISCUSSION

**T**O THE BEST of our knowledge, this is the first study to investigate the efficacy of IS for the prevention of PCs in patients with chest trauma with rib fractures at risk of worsening respiratory failure. In this retrospective study, receiving IS early after the injury was not significantly associated with a difference in PCs. Moreover, no adverse events due to IS were observed.

Most of the previously reported studies on IS have investigated its efficacy in perioperative patients.<sup>6</sup> The operative procedures of the patients included in previous studies were lung surgery,<sup>14,15</sup> esophageal surgery,<sup>16</sup> coronary artery bypass grafting,<sup>17</sup> abdominal surgery<sup>18,19</sup> (including

laparoscopic surgery<sup>20</sup>), bariatric surgery for obese patients,<sup>21</sup> and brain surgery.<sup>22</sup> Furthermore, there were clinical trials that were undertaken in patients with stroke,<sup>23</sup> spinal cord injury,<sup>24</sup> cystic fibrosis,<sup>25</sup> and sickle cell disease.<sup>26</sup> Most of the previous studies, including meta-analyses, in the perioperative setting did not show any significant improvement in patient outcomes with IS,<sup>17,18,27</sup> whereas some studies indicated the effectiveness of IS. A retrospective study that used population-based data suggested that IS reduced hospitalization cost (−\$524.50 per patient) and the risk of pneumonia (odds ratio 0.55) after video-assisted thoracic surgery for lung cancer.<sup>15</sup> Another prospective randomized trial suggested that IS reduced PCs in patients with sickle cell disease by 36.8% (absolute risk reduction).<sup>28</sup>

Patients with chest trauma with rib fractures sometimes presented with respiratory failure due to damage to the lung



**Fig. 2.** Time from hospitalization to the start of incentive spirometry (IS) in patients with chest trauma. In the non-early IS group, patients who did not receive IS were excluded. In the box plots, the boundary of the box closest to zero indicates the 25th percentile, a thick black line within the box marks the median, and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers above and below the box indicate the 10th and 90th percentiles. Points above the whiskers indicate outliers outside the 10th and 90th percentiles. IQR, interquartile range.

**Table 2.** Multivariate regression analyses for primary outcome among patients with chest trauma who received incentive spirometry

	Adjusted odds ratio (95% confidence interval)	P-value
Pulmonary complications	0.71 (0.24–2.16)	0.6
Pulmonary infection	0.76 (0.23–2.47)	0.6
Escalation of oxygen therapy	0.33 (0.03–3.53)	0.4

parenchyma or the thorax. Furthermore, PCs such as pneumonia developed in 13% of those patients<sup>29</sup> and led to a poor prognosis.<sup>2</sup> Respiratory physiotherapy is important for the prevention of PCs, although carrying out sufficient physiotherapy is often more difficult in the acute post-injury phase than it is in perioperative patients. Coexisting injuries, such as fractures of the lower limbs or vertebral fractures, and the difficulty in pain control restricts rehabilitative interventions in trauma patients. Therefore, patients with chest trauma with rib fractures were considered suitable to receive IS voluntarily, self-administered on the bed. Few studies on IS have included trauma patients.<sup>2</sup> A substudy of a prospective observational cohort of non-hospitalized patients with chest trauma with at least one rib fracture did not show any protective effect of IS against PCs (e.g., hemothorax, atelectasis, and pneumonia).<sup>30</sup> A case report described the occurrence of secondary pneumothorax after IS in a postoperative patient with chronic obstructive pulmonary disease.<sup>11</sup> However, IS is generally considered to be safe. We did not find any study that reported the adverse effects of IS in trauma patients.

The findings of this study suggest that patients with chest trauma with rib fractures can safely use IS, although routine IS treatment is not supported in these patients. We think the underestimation of the effectiveness of IS is due to the study limitations, and the difficulty in extracting a suitable group from the highly diverse trauma population meant we were unable to determine a definitive application of IS among chest trauma patients at risk of PCs.

There are some limitations to this study. First, among patients in the early IS group who started IS after withdrawal of mechanical ventilation, several days elapsed between the hospitalization and the start of IS. Although most patients in the early IS group with extremely late IS initiation met the outlier, the effect of IS might have been modified. Second, we were unable to gather information on patient adherence

to IS or the use of a unified protocol for IS. Third, this study was a retrospective observational study, and the treatment allocation was based on physician-specific practices, with randomized allocation. Additionally, the accuracy of the variables was limited because they were defined based on medical record descriptions. Fourth, this analysis was underpowered due to a small sample size. Finally, the influence of unmeasured confounding factors was unavoidable. These methodological weaknesses could have influenced the implications of the results.

## CONCLUSION

FOR PATIENTS WITH chest trauma with rib fractures at risk of worsening respiratory failure, IS early after injury did not reduce the incidence of PCs. No complications with IS were observed, and IS was shown to be a safe intervention for patients with chest trauma. Our results do not support routine use of IS for patients with chest trauma. The preliminary results from this analysis need to be validated in prospective trials under a unified protocol for IS use before application in the clinical setting.

## ACKNOWLEDGMENTS

THE AUTHORS THANK the members of Japanese Society of Education for Physicians and Trainees in Intensive Care (JSEPTIC) Clinical Trial Group for suggesting the study concept and design. We would like to thank Editage for English language editing.

## DISCLOSURE

APPROVAL OF THE research protocol: This retrospective, single-center observational study was approved by the institutional review board of Seirei Hamamatsu General Hospital (No. 3033).

Informed consent: We posted information about this study on the hospital website and gave participants the opportunity to opt-out, and those who did not were considered to have provided tacit consent for study participation.

Registry and the registration no. of the study/trial: N/A.

Animal studies: N/A.

Conflict of interest: None.

## REFERENCES

- Demirhan R, Onan B, Oz K, Halezeroglu S. Comprehensive analysis of 4205 patients with chest trauma: a 10-year experience☆. *Interact Cardiovasc Thorac Surg* 2009; 9: 450–3.

- 2 Martin TJ, Eltorai AS, Dunn R *et al.* Clinical management of rib fractures and methods for prevention of pulmonary complications: a review. *Injury* 2019; 50: 1159–65.
- 3 Ziegler DW, Agarwal NN. The morbidity and mortality of rib fractures. *J Trauma* 1994; 37: 975–9.
- 4 Battle CE, Hutchings H, Evans PA. Risk factors that predict mortality in patients with blunt chest wall trauma: a systematic review and meta-analysis. *Injury* 2012; 43: 8–17.
- 5 Bartlett RH, Krop P, Hanson EL, Moore FD. Physiology of yawning and its application to postoperative care. *Surg Forum* 1970; 21: 222–4.
- 6 Eltorai AEM, Szabo AL, Antoci V *et al.* Clinical effectiveness of incentive spirometry for the prevention of postoperative pulmonary complications. *Respir Care* 2018; 63: 347–52.
- 7 van Aswegen H, Reeve J, Beach L, Parker R, Olsèn MF. Physiotherapy management of patients with major chest trauma: results from a global survey. *Trauma (United Kingdom)* 2020; 22: 133–41.
- 8 Battle CE, Hutchings H, Lovett S *et al.* Predicting outcomes after blunt chest wall trauma: development and external validation of a new prognostic model. *Crit Care* 2014; 18: R98.
- 9 Restrepo RD, Wettstein R, Wittnebel L, Tracy M. Incentive spirometry: 2011. *Respir Care* 2011; 56: 1600–4.
- 10 Alexander JQ, Gutierrez CJ, Mariano MC *et al.* Blunt chest trauma in the elderly patient: how cardiopulmonary disease affects outcome. *Am Surg* 2000; 66: 855–7.
- 11 Kenny JES, Kuschner WG. Pneumothorax caused by aggressive use of an incentive spirometer in a patient with emphysema. *Respir Care* 2013; 58: 77–9.
- 12 The Abbreviated Injury Scale (AIS) 1990 Revision. *Assoc Adv Automot Med*, 1998.
- 13 Kanda Y. Investigation of the freely available easy-to-use software “EZR” for medical statistics. *Bone Marrow Transplant* 2013; 48: 452–8.
- 14 Malik PRA, Fahim C, Vernon J *et al.* Incentive spirometry after lung resection: a randomized controlled trial. *Ann Thorac Surg* 2018; 106: 340–5.
- 15 Liu CJ, Tsai WC, Chu CC, Muo CH, Chung WS. Is incentive spirometry beneficial for patients with lung cancer receiving video-assisted thoracic surgery? *BMC Pulm Med* 2019; 19: 1–8.
- 16 Gosselink R, Schreier K, Cops P *et al.* Incentive spirometry does not enhance recovery after thoracic surgery. *Crit Care Med* 2000; 28: 679–83.
- 17 Freitas ER, Soares BG, Cardoso JR, Atallah ÁN. Incentive spirometry for preventing pulmonary complications after coronary artery bypass graft. *Cochrane Database Syst Rev* 2012; 28: 236–8.
- 18 do Nascimento Junior P, Módolo NS, Andrade S, Guimarães MM, Braz LG, El Dib R. Incentive spirometry for prevention of postoperative pulmonary complications in upper abdominal surgery. *Cochrane Database Syst Rev* 2014: CD006058.
- 19 Tyson AF, Kendig CE, Mabedi C, Cairns BA, Charles AG. The effect of incentive spirometry on postoperative pulmonary function following laparotomy a randomized clinical trial. *JAMA Surg* 2015; 150: 229–36.
- 20 Alaparthy GK, Augustine AJ, Anand R, Mahale A. Comparison of diaphragmatic breathing exercise, volume and flow incentive spirometry, on diaphragm excursion and pulmonary function in patients undergoing laparoscopic surgery: a randomized controlled trial. *Minim Invasive Surg* 2016; 2016: 1967532.
- 21 Pantel H, Hwang J, Brams D, Schnelldorfer T, Nepomnayshy D. Effect of incentive spirometry on postoperative hypoxemia and pulmonary complications after bariatric surgery: a randomized clinical trial. *JAMA Surg* 2017; 152: 422–8.
- 22 Sah HK, Akcil EF, Tunali Y, Vehid H, Dilmen OK. Efficacy of continuous positive airway pressure and incentive spirometry on respiratory functions during the postoperative period following supratentorial craniotomy: a prospective randomized controlled study. *J Clin Anesth* 2017; 42: 31–5.
- 23 Kim CY, Lee JS, Kim HD, Kim IS. Effects of the combination of respiratory muscle training and abdominal drawing-in maneuver on respiratory muscle activity in patients with post-stroke hemiplegia: a pilot randomized controlled trial. *Top Stroke Rehabil* 2015; 22: 262–70.
- 24 Kim CY, Lee JS, Kim HD, Lee DJ. Short-term effects of respiratory muscle training combined with the abdominal drawing-in maneuver on the decreased pulmonary function of individuals with chronic spinal cord injury: a pilot randomized controlled trial. *J Spinal Cord Med* 2017; 40: 17–25.
- 25 Sokol G, Viložni D, Hakimi R *et al.* The short-term effect of breathing tasks via an incentive spirometer on lung function compared with autogenic drainage in subjects with cystic fibrosis. *Respir Care* 2015; 60: 1819–25.
- 26 van Tuijn CFJ, Gaartman AE, Nur E, Rijneveld AW, Biemond BJ. Incentive spirometry to prevent acute chest syndrome in adults with sickle cell disease; A randomized controlled trial. *Am J Hematol* 2020; 10–2.
- 27 Odor PM, Bampoe S, Gilhooly D, Creagh-Brown B, Ramani Moonesinghe S. Perioperative interventions for prevention of postoperative pulmonary complications: systematic review and meta-analysis. *BMJ* 2020; 368: 3–7.
- 28 Bellet PS, Kalinyak KA, Shukla R, Gelfand MJ, Rucknagel DL. Incentive spirometry to prevent acute pulmonary complications in sickle cell diseases. *N Engl J Med* 1995; 333: 699–703.
- 29 Fligel BT, Luchette FA, Reed RL *et al.* Half-a-dozen ribs: the breakpoint for mortality. *Surgery* 2005; 138: 717–25.
- 30 Batomen Kuimi BL, Lague A, Boucher V *et al.* Potential benefits of incentive spirometry following a rib fracture: a propensity score analysis. *Can J Emerg Med* 2019; 21: 464–7.