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Use of an Integrated Pulmonary Index pathway decreased unplanned ICU admissions in elderly patients with rib fractures

Nicholas Davis, Peter Lindbloom, Kathleen Hromatka, Jonathan Gipson, Michaela A West

Trauma, North Memorial Health, Robbinsdale, Minnesota, USA

Correspondence to
Dr Nicholas Davis; Nicholas.Davis@NorthMemorial.com

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ABSTRACT

Unplanned intensive care unit (ICU) admission (UIA) is a Trauma Quality Improvement Program benchmark that is associated with increased morbidity, mortality, and length of stay (LOS). Elderly patients with multiple rib fractures are at increased risk of respiratory failure. The Integrated Pulmonary Index (IPI) assesses respiratory compromise by incorporating SpO_2, respiratory rate, pulse, and end-tidal CO_2 to yield an integer between 1 and 10 (worst and best). We hypothesized that IPI monitoring would decrease UIA for respiratory failure in elderly trauma patients with rib fractures.

Methods Elderly (≥65 years old) trauma inpatients admitted to a level 1 trauma center from February 2020 to February 2023 were retrospectively studied during the introduction of IPI monitoring on the trauma floor. Patients with ≥4 rib fractures (or ≥2 with history of chronic obstructive pulmonary disease) were eligible for IPI monitoring and were compared with a group of chest Abbreviated Injury Scale score of 3 (≥3 rib fractures) patients who received usual care. Nurses contacted the surgeon for IPI ≤7. Patient intervention was left to the discretion of the provider. The primary endpoint was UIA for respiratory failure. Secondary endpoints were overall UIA, mortality, and LOS. Statistical analysis was performed using χ^2 test and Student's t-test, with $p<0.05$ considered significant.

Results A total of 110 patients received IPI monitoring and were compared with 207 patients who did not. The IPI cohort was comparable to the non-IPI cohort in terms of gender, Injury Severity Score, Abbreviated Injury Scale, mortality, and LOS. There were 16 UIAs in the non-IPI cohort and two in the IPI cohort (p=0.039). There were no UIAs for respiratory failure in the IPI group compared with nine in the non-IPI group (p=0.03).

Conclusion IPI monitoring is an easy-to-set up tool with minimal risk and was associated with a significant decrease in UIA in elderly patients with rib fracture.

Level of evidence Level III, therapeutic/care management.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Unplanned intensive care unit (ICU) admission for elderly trauma patients increases the length of stay and mortality. The most common reason for unplanned ICU admissions is respiratory failure.

WHAT THIS STUDY ADDS

⇒ The Integrated Pulmonary Index monitor significantly decreased the risk of unplanned ICU admission in elderly patients with rib fracture.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The Integrated Pulmonary Index monitor is easy to use and interpret and is associated with decreased unplanned ICU admissions in elderly patients with rib fracture.

INTRODUCTION

The demographics of people aged 65 years or older in the USA increased by 38.6% from 2010 to 2020.[1] This large and rapid increase in the elderly population will continue to affect trauma centers as an estimated 30% of all geriatric adults will be admitted to the hospital for traumatic injuries,[2] and approximately 10% of all trauma admissions have rib fractures. Elderly patients with rib fractures are at a greater risk of both pneumonia and mortality compared with younger patients and these risks increase with the number of rib fractures.[3–5] This has led to recommendations for increased levels of care for geriatric patients with rib fractures.[6 7] The Western Trauma Association recommended that patients older than 65 with two or more rib fractures be admitted to the intensive care unit (ICU) for higher level of care and monitoring.[8] Conversely, a recent meta-analysis found insufficient evidence to recommend routine ICU admission for those ≥65 years old with three or more rib fractures, recommending instead use of incentive spirometry to triage older patients.[9]

Unplanned ICU admissions (UIA) remain an issue for elderly trauma patients irrespective of their initial admission status. Geriatric patients with UIA have longer lengths of stay (LOS), more ICU days, and higher mortality rates.[10] Mulvey *et al* found the most common reason for UIA was respiratory failure at 34.7%.[10] The TQIP (Trauma Quality Improvement Project) tracks UIA as a quality metric.[11]

The RibScore, a score based on radiographic rib fracture findings, can help predict which rib fracture patients are at risk of respiratory failure.[12] This can assist in identifying patients who need additional monitoring or interventions. It is unclear which monitoring is most accurate in identifying pending respiratory failure. Predicting which patients with high risk for respiratory failure that will progress to UIA is challenging because patient's comorbidities,

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concomitant injuries, and medications can make standard vital signs misleading.[13] A Cochrane review in 2014 focused only on continuous pulse oximetry monitoring showed no benefit in rates of UIA in postoperative cardiothoracic patients cared for on the ward .[14] Geriatric patients also present a treatment challenge because of their varying reserve capacities. Attempts have been made to use end-tidal CO_2 ($ETCO_2$) monitoring to identify respiratory distress in ward patients, but the accuracy of $ETCO_2$ monitoring is complicated by increased dead space ventilation and mixing of expired air with room air. Pekdemir *et al* found that neither mainstream nor sidestream $ETCO_2$ values correlated well with arterial $PaCO_2$ levels.[15]

The Capnostream 20p (Medtronic, Dublin, Ireland) bedside capnography monitor was developed as a tool to assist with bedside assessment of respiratory status.[16] It uses capnography to measure $ETCO_2$ and simultaneously measures oxygen saturation (SpO_2), respiratory rate, and pulse. These four values are used to create an Integrated Pulmonary Index (IPI) number, which is an integer between 1 and 10 generated using fuzzy logic.[17] The manufacturer recommends that the scoring system be interpreted as follows: 8–10 is a normal respiratory status, 7 is near normal requiring attention, 5–6 requires attention and possible intervention, 3–4 requires immediate intervention, and 1–2 requires immediate assessment and intervention. The utility of the IPI has been validated in multiple areas of patient care.[16,17]

In 2020, our institution implemented IPI monitoring as a quality improvement initiative for high-risk geriatric patients with multiple rib fractures. We hypothesized that IPI monitoring would identify patients with impending respiratory failure and therefore decrease UIA for respiratory failure in geriatric blunt trauma patients with multiple rib fractures.

METHODS

The current study is a retrospective review of trauma patients admitted to a community level 1 trauma center between February 2020 and February 2023. The study followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.

In February 2020, our hospital began IPI monitoring for elderly patients with rib fracture at high risk for respiratory failure. Patients ≥65 with four or more rib fractures, or two rib fractures and chronic obstructive pulmonary disease (COPD), were considered high risk and recommended to have IPI monitoring once they were admitted to the trauma unit. Per the protocol, nursing was instructed to contact the trauma provider for an IPI score of ≤7. Providers used their discretion in evaluating and managing the patient. Patients whose IPI scores were ≥8 for 72 hours completed the protocol and were taken off IPI monitoring. During the study period, not every eligible elderly trauma patient was offered, or agreed to receive, IPI monitoring.

Enrollment in the IPI cohort was done prospectively. IPI monitoring was done only on the trauma unit. Patients transferred from the ICU to the trauma unit were also eligible for IPI monitoring. To assess the value of IPI monitoring in patients who met criteria, we compared IPI-monitored patients to a non-IPI-monitored cohort from the same time period, February 2020 to February 2023. The comparator group was identified retrospectively using data from our institutional trauma registry. Inclusion criterion for the comparator group was patients ≥65 years with chest Abbreviated Injury Scale (AIS) score of ≥3. This inclusion criterion was selected to identify a cohort of patients who most closely matched the chest wall injuries in the IPI group. Patients were excluded if they did not meet inpatient criteria, were not treated on the trauma unit, or did not have restorative care on the floor (death in ICU or emergency room, discharged from ICU, or on comfort care only measures at admission or transition out of the ICU). Review of the electronic health record was performed to collect additional data for both cohorts including the number of rib fractures. Any patient who had initiation of IPI monitoring, but subsequently stopped IPI monitoring prior to completion of the protocol, was analyzed as a member of the IPI group.

The demographics of all subjects were compiled, including gender, age, admission COVID status, mechanism of injury, Injury Severity Score (ISS), chest AIS, and number of rib fractures. These were compared between the two cohorts. Additional data for the IPI group were collected including IPI numbers, provider notifications, diagnostic tests, and interventions. An intervention due to low IPI was only considered such if there was documentation linking the low IPI to the intervention. The primary outcome was UIA due to respiratory failure. Respiratory failure was defined as worsening hypoxemia or hypercapnia requiring intubation or non-invasive ventilation. A UIA was defined as any unexpected ICU admission from the trauma unit regardless of the patient's original admission unit. During the time of this study, our institution did not have an intermediary care unit, or step down unit. Secondary outcomes included UIA for reasons other than respiratory failure, pneumonia, mortality, and LOS.

Our institution uses a rib fracture management protocol for patients with rib fractures. The protocol uses multimodal pain management including oral narcotics, non-steroidal anti-inflammatory drugs, acetaminophen, muscle relaxant, and lidocaine transdermal patches. The patients are educated on incentive spirometry use with a goal of 15 mL/kg. When that goal is not met, respiratory therapy is consulted and Ez-PAP (ICU Medical Inc., San Clemente, CA) is initiated. The ICU is recommened at admission in geriatric patients with four or more rib fractures or those needing supplemental oxygen.

Study data were collected and managed using REDCap (Nashville, TN) electronic data capture tools hosted at our institution.[18,19] Statistical analysis was done using Pearson's χ^2 test, Student's t-test, and Fisher's exact test. Statistical significance is defined as p value ≤0.05.

RESULTS

There were a total of 110 patients in the IPI-monitored group and 207 patients in the non-IPI-monitored group (figure 1). Table 1 compares the demographics and baseline characteristics of the IPI and non-IPI cohorts and shows the cohorts had no statistically significant difference in terms of ISS, chest AIS, and number of rib fractures. The IPI group had an older average age of 79.0 versus 76.9 (p=0.34). The IPI group had a slightly higher proportion of COPD and greater need for chest tube placements, neither of which were statistically significant. The table shows that a history of smoking, stroke, and congestive heart failure were significantly higher in the IPI group. The most common mechanism of injury for each group was fall from standing, followed by motor vehicle crash and fall from height. A significant difference was seen in patients with COVID-19 in the non-IPI cohort comparted with the IPI cohort (11 vs. 0, p=0.01), but none of the patients admitted with COVID-19 had a UIA.

Table 2 shows the UIA, comparing IPI and non-IPI cohorts. A total of 18 patients had UIA for any reason, 16 in the non-IPI group and two in the IPI group (p=0.039). In the non-IPI group, nine had UIA secondary to respiratory failure and seven for

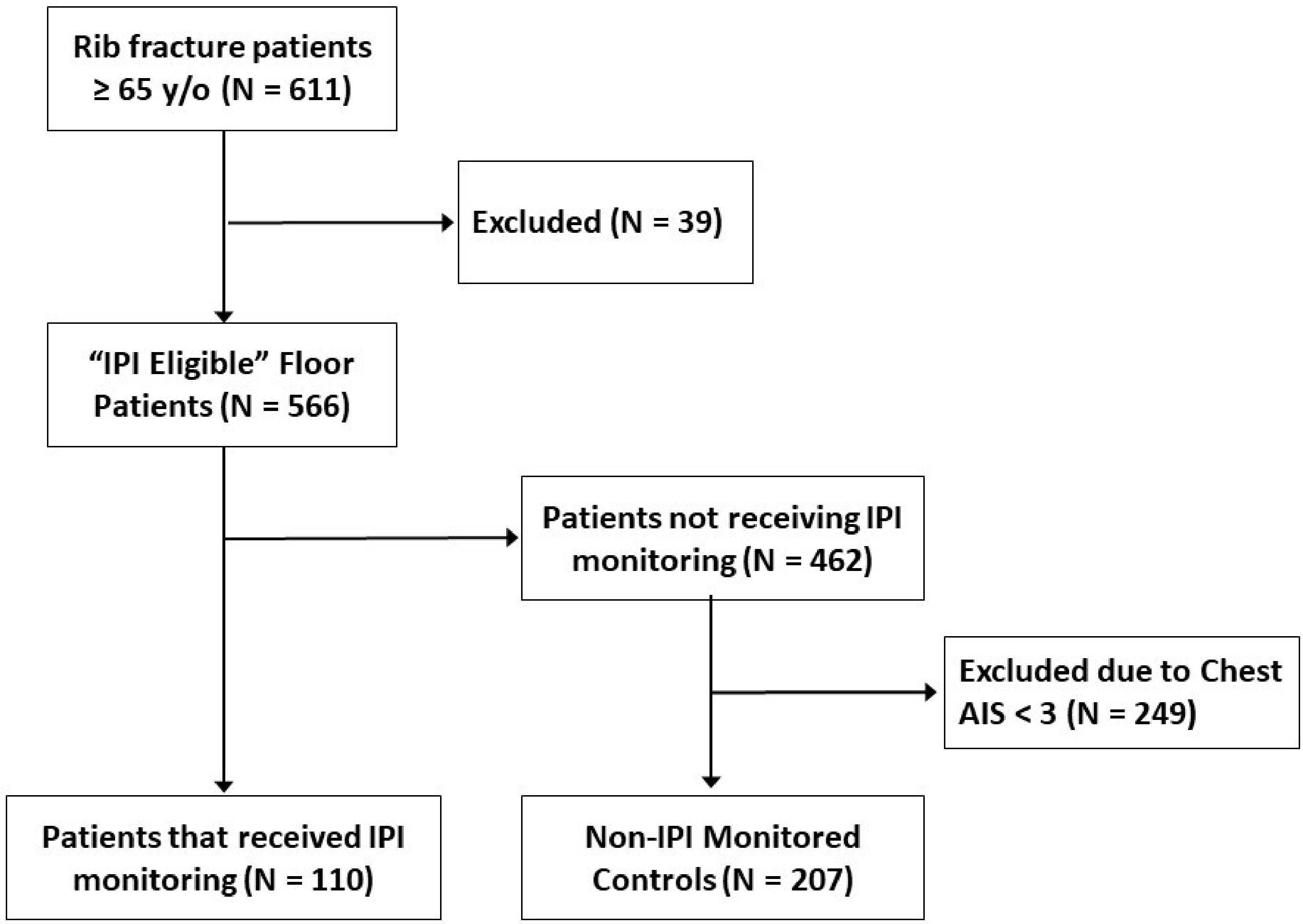

Figure 1 CONSORT diagram. AIS, Abbreviated Injury Scale; IPI, Integrated Pulmonary Index.

non-respiratory reasons (3 hypotension, 2 worsening traumatic brain injury (TBI), 1 stroke, and 1 symptomatic hyponatremia). In the IPI group, there were two UIAs secondary to gastrointestinal bleeding with hypotension that occurred when the patient was no longer undergoing IPI monitoring. One patient had completed the protocol with an IPI score of ≥8 for 72 hours, while the other refused continued monitoring after 5 days.

None of the patients in the IPI group had UIA for respiratory failure (p=0.03). In the non-IPI group, nine UIAs were due to respiratory failure, and five of these patients required intubation. The remaining four all had biphasic positive airway pressure (BiPAP), three for increasing hypoxemia and one for sustained tachypnea with a respiratory rate in the 30s. Table 2 also shows that there were no differences between the groups in rates of pneumonia or LOS. No statistically significant difference was seen with respect to mortality. There were five deaths in the non-IPI group versus two in the IPI group (p=0.757). In the non-IPI group, all the deaths were related to patient and family decisions to transition to comfort care measures. Of these non-IPI deaths, four were UIA and occurred in the ICU (1 compassionate extubation, 2 removed from BiPAP, and 1 due to worsening TBI) and one was on the trauma unit (removed from BiPAP). In the IPI group, one death occurred in the ICU due to pulseless electrical activity secondary to gastrointestinal bleed, and the other due to comfort care measures on the floor.

In the IPI group, 57 (56%) patients had a lowest IPI score of ≤7 (see figure 2). There were 21 (39%) documented provider notifications in the electronic medical record (EMR), resulting in 19 interventions. The other two cases had no documentation of further evaluation or treatment. Four notifications led to diagnostic testing (chest X-ray or venous blood gas), and these were considered normal, and no further interventions followed. In the remaining 15 patients with notifications, interventions were performed and the IPI improved in all 15 patients. The most common intervention was increased pain control (n=6), followed by chest tube placement (n=3), nebulizer treatment (n=2), BiPAP (n=1), high-flow nasal cannula (HFNC; n=1), epidural placement (n=1), and treatment of hypoglycemia (n=1). All patients who were placed on BiPAP and HFNC stabilized, did not require subsequent increased FiO_2, and were able to remain on the trauma unit. The remaining 53 patients had an IPI score of 8 or greater, and only one needed intervention (see figure 2). The one patient requiring intervention had no change in respiratory status but developed a retained hemothorax that required chest tube placement.

DISCUSSION

None of the high-risk geriatric patients with rib fracture who had IPI monitoring had a UIA for respiratory failure. Use of the IPI monitoring protocol resulted in a statistically significant decrease in the primary endpoint, UIA for respiratory failure, when compared with standard of care using intermittent vital sign checks. Additionally, there was a statistically

Table 1 Demographics of elderly patients with multiple rib fractures: comparison of non-IPI vs. IPI groups

Parameter	Non-IPI	IPI	P value
Number of subjects	207	110	
ISS, mean (±SD)	14.1±6.3	13.2±6.1	0.191
Chest AIS, mean (±SD)	3.01±0.1	2.99±0.3	0.395
Number of rib fractures, median (IQR)	4 (1)	5 (2)	0.062
Age in years, mean (±SD)	76.9±8.6	79.0±9.0	0.034
Gender, n (%)			
Female	91 (44.0)	45 (40.9)	0.600
Male	116 (56.0)	65 (59.1)	
Initial ICU admission, n (%)	142 (68.5)	65 (59.1)	0.090
Chest tube, n (%)	40 (19.3)	26 (23.6)	0.305
Flail chest, n (%)	8 (3.8)	4 (3.6)	0.957
Pulmonary contusion, n (%)	12 (5.7)	7 (6.4)	0.792
COPD, n (%)	27 (13.0)	17 (15.4)	0.570
COVID, n (%)	11 (5.3)	0 (0)	0.014
Hypertension, n (%)	123 (59.4)	72 (65)	0.237
Diabetes, n (%)	48 (23.2)	26 (23.6)	0.899
Anticoagulated, n (%)	36 (17.4)	15 (13.6)	0.387
Smoker, n (%)	25 (12.1)	30 (37.5)	0.007
CHF, n (%)	8 (3.9)	12 (10.9)	0.011
History of stroke, n (%)	4 (1.9)	9 (8.2)	0.007
Epidural placement, n (%)	3 (1.4)	1 (1)	0.681
Mechanism of injury, n (%)			
Fall from standing	135 (65.2%)	60 (54.5)	0.124
MVC	33 (15.9%)	21 (19.1)	0.478
Fall from height	16 (7.7%)	15 (13.6)	0.109
MCC	5 (2.4%)	6 (5.5)	0.145
Pedestrian	6 (2.9%)	3 (2.7)	0.963
Bicycle crash	9 (4.3%)	3 (2.7)	0.500
Other	3 (1.4%)	2 (1.8)	0.800

AIS, Abbreviated Injury Scale; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; ICU, intensive care unit; IPI, Integrated Pulmonary Index; ISS, Injury Severity Score; MCC, motorcycle crash; MVC, motor vehicle crash.

significant prevention of all-cause UIA, which was largely driven by decreased UIA due to respiratory failure. Overall, the study had a 5.7% (18/313) rate of UIA. This number is consistent with other studies, but our study only reviewed one segment of geriatric trauma.[6 10] Consistent with the Mulvey *et al* study, we found that respiratory issues were the most common cause of UIA at 50% (9/18).[10]

Table 2 Outcome comparison of non-IPI and IPI cohorts

Parameter	Non-IPI	IPI	P value
UIA	16	2	0.039
UIA for respiratory failure	9	0	0.030
Mortality	5	2	0.757
Pneumonia	12	7	0.792
UIA return to ICU	62.5% (10)	50% (1)	0.732
LOS (mean±SD)			
Overall	6.6±6.7	5.7±4.4	0.224
UIA	14.2±7.9	15.0±7.1	0.889

ICU, intensive care unit; IPI, Integrated Pulmonary Index; LOS, length of stay; UIA, unplanned ICU admission.

A key component of the IPI monitoring intervention was early recognition and treatment of respiratory decompensation. In the IPI group, a provider was notified 21 times by the nurse staff for an IPI score of less than 7. Of those, 15 led to interventions and the IPI number improved in each instance. Only two of these interventions were time critical treatments: hypoxemia treated with a nebulizer and hypoglycemia treated with D50. Even though the remaining interventions were not time sensitive, they all improved the IPI value. This suggests that early interventions prompted by the IPI monitoring prevented further progression of respiratory insufficiency.

Khanna *et al* advocated for the potential of continuous vital sign monitoring on the ward to decrease adverse events.[20] The author points out that patients rarely deteriorate without warning. Rather, they have early vital sign changes that precede the deterioration. When vital signs are collected periodically, as is most often done on the floor, these subtle early vital sign changes are often missed. Eddahchouri *et al* demonstrated that continuous remote vital sign monitoring decreased UIA in medical and surgical patients.[21] It should be noted that the IPI number was not continuously monitored at a central station or recorded in a continuous manner. The machine was continuously present in the patient's room, providing staff with many more vital sign observations compared with intermittent vital signs.

A Cochrane review showed no reduction in UIA for postoperative patients with continuous oximetry and a study by McGrath *et al* showed that monitoring of the respiratory rate does not contribute to early detection of respiratory deterioration.[14 22] These articles only focused on SpO_2 and respiratory rate. In contrast, the IPI number incorporates the RR, SpO_2, $ETCO_2$, and pulse into a single number, simplifying the interpretation of changes in these vital signs. Continuous IPI monitoring may also lead to earlier interventions by providers, as subtle changes in any one of the incorporated vital signs could have otherwise been missed by the care team.

Other strategies for decreasing UIA in rib fractures have also been studied. The Rib Injury Guidelines (RIG), published during our study period, demonstrated a lower initial ICU admission rate with only two UIAs.[23] The study showed the RIG score was an effective triage tool for admission of patients with rib fracture. In the study, the RIG score was not used as criterion for transfer out of the ICU. Transfer out of our trauma ICU for patients with rib fracture is recommended once the patient has achieved the incentive spirometer (IS) goal. In the non-IPI group, six of the nine respiratory failure UIAs had an initial ICU admission. The IPI group had a lower initial ICU admission rate and only two UIAs, none of which were for respiratory failure. Another rib fracture scoring system, the Pain Inspiration Cough (PIC) score, uses pain, inspiration (measured with IS), and cough to identify patients with rib fracture needing further evaluation.[24] Jones *et al* found that the PIC score led to 34% of patients getting appropriate nurse to provider notifications when scores were low, but this resulted in no change in LOS.[25] Similar to this study, the PIC score was used as early warning for impending respiratory failure, and it appropriately alerted providers but did not affect LOS.

This study has several limitations inherent in retrospective studies. There was no mitigation for selection bias in the study. Providers were encouraged but not required to use IPI monitoring for geriatric patients with four or more rib fractures. The chest AIS, number of rib fractures, and ISS between the two groups were similar, but providers may have chosen to use IPI monitoring based on other clinical concerns. It was not possible to assess the temporal relationship between IPI changes, provider

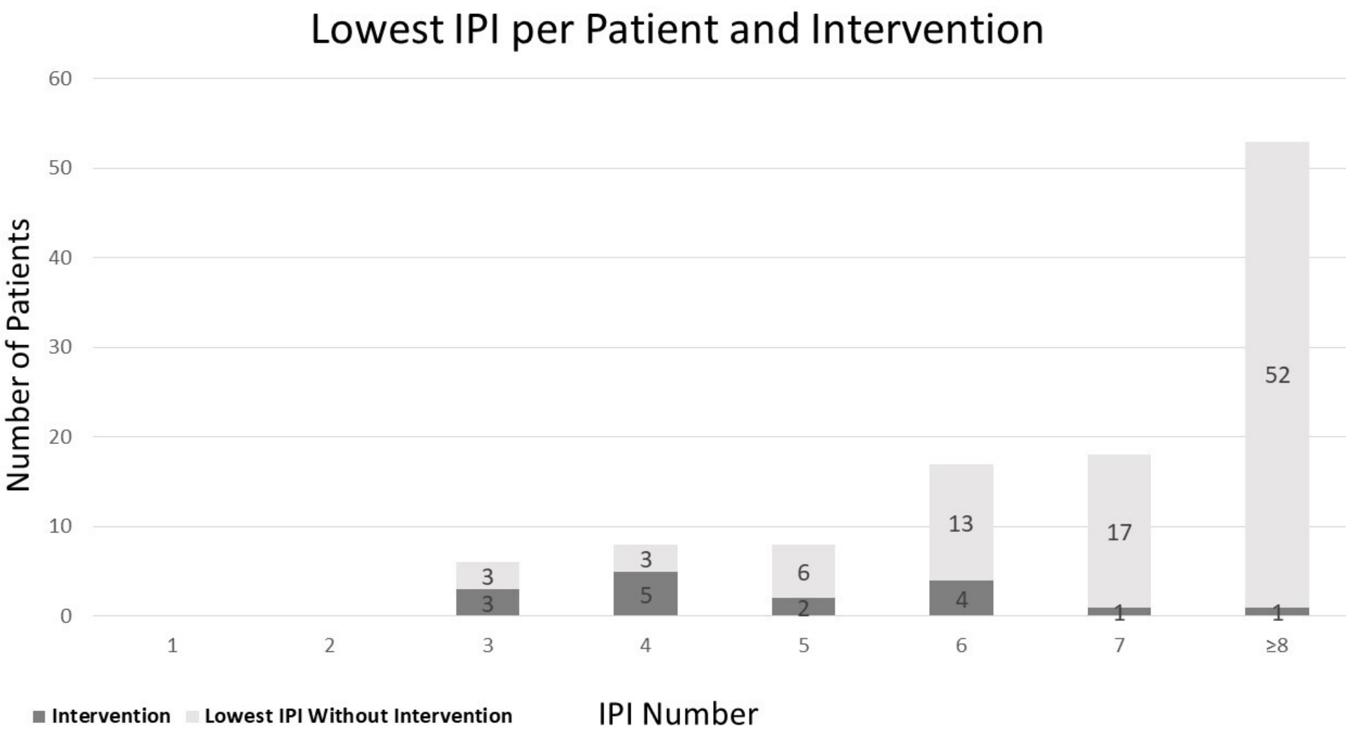

Figure 2 Lowest Integrated Pulmonary Index (IPI) number and intervention.

notification, and subsequent intervention in every patient situation due to intermittent missing data in the electronic record. Only documented provider notifications were considered in the study. We were unable to account for non-documented nurse–provider interactions related to IPI monitoring. Missing data also limited the ability of the study to measure the accuracy of the IPI number in identifying respiratory deterioration and the number of false positives (IPI score ≤7 without respiratory deterioration). We are unable to determine the overutilization of resources needed to address the false positives.

While not a limitation of the study, a limitation with the Capnostream 20p monitor is chronic alarming. With continuous monitoring comes the risk of increased alarms. This adversely affects patients in two main ways. The first is care team alarm fatigue. Bedside providers with continuous monitoring systems can be exposed to 100–350 alarms per day.[26] This can lead to an increase in response time and desensitization to the alarm.[27] The second is noise nuisance to the patient. This can lead to patient dissatisfaction and sleep interruption.[28] Three patients had documented refusal to use the machine due to complaints of persistent alarming during set-up and five patients prematurely ended IPI monitoring due to chronic alarming. Patient compliance with IPI monitoring could be improved with alarm reduction strategies.

In summary, IPI monitoring showed promise as an indicator for impending respiratory failure in geriatric patients with rib fractures, with an associated decreased risk of UIA. Use of IPI monitoring warrants prospective multicenter studies to further assess effectiveness in decreasing UIA in all trauma patients at risk for respiratory failure.

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Patient consent for publication Not applicable.

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ORCID iDs
Nicholas Davis http://orcid.org/0009-0009-0845-8423
Michaela A West http://orcid.org/0000-0002-6598-4114

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