Feasibility and safety of in-bed cycling for physical rehabilitation in the intensive care unit

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A R T I C L E   I N F O

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Respiration
Artificial
Muscle

A B S T R A C T

Purpose: The purpose was to evaluate the feasibility and safety of in-bed cycle ergometry as part of routine intensive care unit (ICU) physical therapist (PT) practice.

Materials and methods: Between July 1, 2010, and December 31, 2011, we prospectively identified all patients admitted to a 16-bed medical ICU receiving cycling by a PT, prospectively collected data on 12 different potential safety events, and retrospectively conducted a chart review to obtain specific details of each cycling session.

Results: Six hundred eighty-eight patients received PT interventions, and 181 (26%) received a total of 541 cycling sessions (median [interquartile range {IQR}] cycling sessions per patient, 2 [1-4]). Patients’ mean (SD) age was 57 (17) years, and 103 (57%) were male. The median (IQR) time from medical ICU admission to first PT intervention and first cycling session was 2 (1-4) and 4 (2-6) days, respectively, with a median (IQR) cycling session duration of 25 (18-30) minutes. On cycling days, the proportion of patients receiving mechanical ventilation, vasopressor infusions, and continuous renal replacement therapy was 80%, 8%, and 7%, respectively. A single safety event occurred, yielding a 0.2% event rate (95% upper confidence limit, 1.0%).

Conclusions: Use of in-bed cycling as part of routine PT interventions in ICU patients is feasible and appears safe. Further study of the potential benefits of early in-bed cycling is needed.

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1. Introduction

Survivors of critical illness frequently report long-term physical impairments persisting up to 5 years after discharge [1,2]. Rehabilitation, such as physical therapy (PT) interventions in the intensive care unit (ICU), can improve patients’ outcomes. A systematic review of randomized controlled trials (RCTs) of strategies to improve physical function of ICU survivors identified the importance of PT interventions in the ICU [3]. However, implementing evidence-based PT interventions, as part of routine clinical practice, can be challenging [4-6]. Such challenges include access to rehabilitation personnel and specialized equipment, and ICU patients’ physiological stability [7-9].

Some rehabilitation interventions in critically ill patients require additional human resources. For example, a 330-patient study added a mobility team, consisting of a PT, registered nurse, and nurse assistant, to facilitate early mobility [10]. A 104-patient RCT of early rehabilitation used both a PT and occupational therapist for interventions [11]. With a projected increase in the number of critically ill patients requiring rehabilitation in the ICU [12] and a concurrent projected decrease in the number of PTs available to provide care [13-15], effective and efficient rehabilitation interventions are needed.

One promising technology that may be both effective and efficient for rehabilitation of critically ill patients is in-bed cycle ergometry (“cycling”). In a 90-patient, single-center RCT of in-bed cycling in the ICU vs usual care, those receiving cycling demonstrated better 6-minute walk distance, greater leg strength, and better Short Form 36 physical function scores at hospital discharge [16]. However, few ICUs have in-bed cycle ergometers [8]; thus, there are little data regarding use of cycling as part of routine care in the ICU. Following publication of the RCT of cycling [16], our ICU purchased an in-bed cycle ergometer (Reck MotoMed Letto) similar to that reported in the trial. Within an individual cycling session, as dictated by the patients’ level of wakefulness, participation, and effort, this device...
allows patient activity to move back and forth between passive cycling (where the patient does not contribute to pedal motion), active-assisted cycling (where the patient can augment the motorized cycle), and active cycling (with the option for a PT to add resistance to cycling). In this report, we evaluated the feasibility and safety of incorporating in-bed cycle ergometry as part of routine PT practice in the ICU.

2. Materials and methods

We identified all adult patients admitted to a 16-bed medical ICU (MICU) who received PT interventions between July 1, 2010, and December 31, 2011, from a prospectively collected clinical database of critical care physical rehabilitation. For all such patients, we retrospectively collected additional data on all cycling sessions, including the duration of sessions, whether active cycling occurred, and the number of PT intervention sessions per patient. The median (IQR) time from MICU admission to first PT session was 2 (1-3) days, and the number of MICU PT intervention sessions per patient was 2 (1-4). Compared with patients who did not receive in-bed cycling during their MICU stay, patients who cycled were more likely to receive mechanical ventilation (82% [149] vs 55% [281], P < .001), received a greater number of PT intervention sessions per patient (2 (1-4) vs 1 (1-3), P < .001), and had a lower ICU mortality (52% [281] vs 7.6% [286], P < .001). Patients who received in-bed cycling were more likely to receive mechanical ventilation (82% [149] vs 55% [281], P < .001), received a greater number of PT intervention sessions per patient (2 (1-4) vs 1 (1-3), P < .001), and had a lower ICU mortality (52% [281] vs 7.6% [286], P < .001). Patients who received in-bed cycling were more likely to receive mechanical ventilation (82% [149] vs 55% [281], P < .001), received a greater number of PT intervention sessions per patient (2 (1-4) vs 1 (1-3), P < .001), and had a lower ICU mortality (52% [281] vs 7.6% [286], P < .001).

### Table 1

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All patients</th>
<th>Cycling n = 181</th>
<th>No cycling n = 507</th>
<th>P value</th>
</tr>
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<tbody>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (y), mean [SD]</td>
<td>56.7 (14.1)</td>
<td>56.7 (16.6)</td>
<td>56.6 (16.0)</td>
<td>.977</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>332 (48.3)</td>
<td>103 (69.6)</td>
<td>229 (45.2)</td>
<td>.007</td>
</tr>
<tr>
<td>Black race, n (%)</td>
<td>350 (50.9)</td>
<td>82 (54.3)</td>
<td>268 (52.9)</td>
<td>.004</td>
</tr>
<tr>
<td>Location before hospital admission</td>
<td></td>
<td></td>
<td></td>
<td>.476</td>
</tr>
<tr>
<td>Home (independent)</td>
<td>444 (65.1)</td>
<td>122 (67.8)</td>
<td>322 (63.5)</td>
<td></td>
</tr>
<tr>
<td>Home (with caregiver assistance)</td>
<td>192 (27.9)</td>
<td>44 (24.4)</td>
<td>148 (29.2)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>51 (7.4)</td>
<td>14 (7.8)</td>
<td>37 (7.3)</td>
<td></td>
</tr>
<tr>
<td>Ambulatory before ICU admission</td>
<td>604 (85.6)</td>
<td>155 (85.6)</td>
<td>449 (88.6)</td>
<td>.302</td>
</tr>
<tr>
<td>Location before MICU admission</td>
<td></td>
<td></td>
<td></td>
<td>.005</td>
</tr>
<tr>
<td>Ward</td>
<td>252 (36.0)</td>
<td>61 (33.7)</td>
<td>191 (38.0)</td>
<td></td>
</tr>
<tr>
<td>Emergency department</td>
<td>246 (36.0)</td>
<td>53 (29.3)</td>
<td>193 (38.4)</td>
<td></td>
</tr>
<tr>
<td>Outside hospital</td>
<td>152 (22.3)</td>
<td>56 (30.9)</td>
<td>96 (19.1)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>33 (4.8)</td>
<td>11 (6.1)</td>
<td>22 (4.4)</td>
<td></td>
</tr>
<tr>
<td>ICU admission diagnosis, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>.003</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>315 (45.8)</td>
<td>101 (55.8)</td>
<td>214 (42.2)</td>
<td></td>
</tr>
<tr>
<td>Sepsis, nonpulmonary</td>
<td>114 (16.6)</td>
<td>25 (13.8)</td>
<td>89 (17.6)</td>
<td></td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>91 (13.2)</td>
<td>15 (8.3)</td>
<td>76 (15.0)</td>
<td></td>
</tr>
<tr>
<td>Nephrology</td>
<td>45 (6.5)</td>
<td>11 (6.1)</td>
<td>34 (6.7)</td>
<td></td>
</tr>
<tr>
<td>Cardiopulmonary arrest</td>
<td>19 (2.8)</td>
<td>9 (5.0)</td>
<td>10 (2.0)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>104 (15.1)</td>
<td>20 (11.0)</td>
<td>84 (16.6)</td>
<td></td>
</tr>
<tr>
<td>Received mechanical ventilation during MICU stay, n (%)</td>
<td>430 (62.5)</td>
<td>149 (82.3)</td>
<td>281 (55.4)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Days from MICU admission to first PT session, median (IQR) per patient</td>
<td>2 (1-3)</td>
<td>2 (1-4)</td>
<td>2 (1-3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>No. PT treatments in MICU, median (IQR) per patient</td>
<td>2 (1-4)</td>
<td>4 (3-9)</td>
<td>2 (1-3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>ICU mortality</td>
<td>52 (7.6)</td>
<td>28 (15.5)</td>
<td>24 (4.7)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MICU LOS, all patients, median (IQR) days</td>
<td>4 (2-8)</td>
<td>10 (5-17)</td>
<td>3 (2-6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hospital mortality</td>
<td>95 (13.8)</td>
<td>49 (27.1)</td>
<td>46 (9.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hospital LOS, all patients, median (IQR) days</td>
<td>13 (7-24)</td>
<td>20 (12-35)</td>
<td>11 (6-19)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Discharge location among survivors, n (%)</td>
<td>198 (33.4)</td>
<td>28 (21.2)</td>
<td>170 (36.9)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Home (independent)</td>
<td>130 (21.9)</td>
<td>20 (15.2)</td>
<td>110 (23.9)</td>
<td></td>
</tr>
<tr>
<td>Home (with caregiver assistance)</td>
<td>72 (12.1)</td>
<td>27 (20.5)</td>
<td>45 (9.8)</td>
<td></td>
</tr>
<tr>
<td>Acute rehabilitation</td>
<td>78 (13.2)</td>
<td>27 (20.5)</td>
<td>51 (11.1)</td>
<td></td>
</tr>
<tr>
<td>Subacute rehabilitation</td>
<td>115 (19.4)</td>
<td>30 (22.7)</td>
<td>85 (18.4)</td>
<td></td>
</tr>
</tbody>
</table>

In this table, we compare characteristics of patients receiving physical therapy and in-bed cycle ergometry with those who did not receive cycle ergometry. For binary data, we calculated the proportion and 95% confidence interval. We used a t test for independent groups to compare continuous data [19] and used the χ² statistic (or Fisher exact test, as appropriate) to compare categorical data. JHH indicates Johns Hopkins Hospital.

* Sample size for cycling and noncycling, respectively: 180, 507.
† Sample size for cycling and noncycling, respectively: 181, 502.
sessions (4 [3-9] vs 2 [1-3], P <.001), and had a longer MICU length of stay (median [IQR] days, 10 [5-17] vs 3 [2-6], P <.001).

Of the 181 patients receiving cycling, the mean (SD) age was 57 (16) years, 103 (57%) were male, and 82 (45%) were black (Table 1). Before hospital admission, most patients could ambulate (155 [86%]) and lived independently at home (122 [68%]). The main categories for MICU admission were respiratory failure (101 [56%]), nonpulmonary sepsis (25 [14%]), or gastrointestinal issues (18 [8%]). The mean (SD) admission SOFA score was 8.4 (3.8), and median (IQR) time from MICU admission to first PT intervention and first cycling session was 2 (1-4) and 4 (2-6) days, respectively (Tables 1 and 2). Patients received 541 cycling sessions by 9 different PTs with a median (IQR) number of PT intervention and cycling sessions of 4 (3-9) and 2 (1-4) per patient, respectively.

### 3.1. Feasibility of in-bed cycling

Patients received the following ICU therapies on 541 cycling days (Table 3): mechanical ventilation (432 [80%], of whom 268 [62%] had an oral endotracheal tube), vasopressor infusion (45 [8%]), and CRRT (36 [7%]). Infusions of a benzodiazepine, propofol, or opioid occurred on 128 (24%), 62 (11%), and 206 (38%) of all cycling days, respectively. (36 [7%]). Infusions of a benzodiazepine, propofol, or opioid occurred on 128 (24%), 62 (11%), and 206 (38%) of all cycling days, respectively.

Among all 12 physiological abnormalities or potential safety events prospectively monitored with the 541 cycling sessions, only a single event occurred (0.2% event rate, 95% upper confidence limit = 1.0%). This event was dislodgement of a radial arterial line already scheduled for replacement due to unstable positioning and malfunction before cycling.

### 4. Discussion

To our knowledge, this evaluation of 181 consecutive patients receiving 541 in-bed cycling sessions as part of routine clinical care with PT interventions in the MICU is the largest-sized report to date. Medical ICU patients receiving (vs not receiving) in-bed cycling were more severely ill with more PT intervention treatments and a longer ICU length of stay. For those patients who received in-bed cycling, PTs included cycling in approximately half of all treatment sessions. The majority of in-bed cycling sessions occurred on days in which patients received mechanical ventilation. Cycling also occurred on days when patients received vasopressor infusions and CRRT, and had femoral vascular access devices in situ. The frequent use of cycling, as reported in our data, demonstrates that it is a feasible rehabilitation therapy intervention for ICU patients. In particular, this intervention may be most suitable for ICU patients who cannot tolerate out-of-bed activities, such as standing, transferring to chair, or walking. Safety events were rare (0.2% event rate) with only a single event (ie, dislodgement of a radial arterial catheter previously identified for replacement due to malposition and malfunction before cycling). Hence, these data suggest that cycling is feasible and safe as part of routine PT interventions in the ICU.

In-bed cycling is a promising technology to enhance rehabilitation in critically ill patients [9]. To date, 6 ICU studies have reported cycling in a total of 173 patients [16,20-24] with more than 600 sessions reported [16,21-24]. Of these 6 reports, there were 3 case series [21-23], 1 case-control study [24], and 2 RCTs [16,20], with sample sizes varying from 16 (24) to 90 (16) enrolled patients. These reports included evaluation of single cycling sessions [21-23], cycling as part of a rehabilitation therapy protocol [20], cycling added to usual-care PT interventions [16], and cycling augmented by electrical stimulation [24]. Reported cycling session duration was less than or equal to 5 [20,22], 20 minutes [16,21], and greater than or equal to 30 minutes [23,24], and occurred during receipt of mechanical ventilation [16,20-24] and vasopressors [16,21-24]. Two studies using a control group compared cycling to usual care [16,20].

The largest study to date was a 90-patient, single-center RCT of 20 minutes of in-bed cycling delivered 5 days per week in addition to usual PT interventions [16]. This trial was conducted in Belgian medical-surgical patients, randomizing 45 patients to the cycling intervention with 425 cycling sessions received. Participants received a median (IQR) of 7 (4-11) sessions; 45% and 87% cycled actively during their first and last ICU cycling sessions, respectively [16]. Patients were randomized to cycling, on average, 14 days after ICU admission, with 84% mechanically ventilated at trial entry [16]. Patients randomized to cycling vs usual care had a greater median 6-minute walk test distance at hospital discharge (196 m vs 143 m, P < .05) as the primary outcome [16]. Those receiving cycling also had greater quadriceps force (P < .05) and Short Form 36 physical function scores (P < .01) at hospital discharge [16].

Similar to the RCT [16], our mean patient age was 57 years old, approximately 80% received mechanical ventilation, and patients cycled for a median of 25 minutes per session. In contrast, we studied exclusively medical ICU patients, whereas surgical patients accounted for almost 80% of those in the prior RCT (39% cardiac, 25% transplant, and 16%...
logical abnormalities as previously de
no unplanned extubation, and there were no cardiorespiratory physio-

routine care. We evaluated a cohort of 181 consecutive patients receiving 541 in-
bed cycling sessions as part of routine PT interventions in a single MICU. In this setting, cycling started relatively early during their ICU stay and

Our study has potential limitations. Firstly, although we prospective-
ly identified all cycling sessions and safety data, details about the cycling sessions were retrospectively collected from PT clinical notes; hence, we do not have data regarding why therapists chose cycling as part of their treatment session. Secondly, we did not collect daily organ failure scores or patient comorbidities. Previous research suggests that the time to ini-
tiation of PT interventions in the ICU is longer in patients with higher vs lower severity of illness and organ failure scores [25]. Moreover, patient comorbidities may impact exercise tolerance, and greater comorbidity

is associated with poorer physical function [26]. Thirdly, we have no data on patients' physical functional outcomes at ICU initial assessment, ICU discharge, or hospital discharge, or data on patients' perceptions of in-bed cycling.

In-bed cycling was provided by PTs experienced with MICU rehabili-
tation and trained to provide in-bed cycling, which could impact the generalizability of safety data to other ICU settings where therapists are not experienced with ICU-based rehabilitation or in-bed cycling. To facilitate implementation of cycling, PTs in our institution learn about technical operation of the cycle ergometer (eg, patient set up, cycle functioning) and patient characteristics required for cycling (eg, maximum patient weight = 150 kg; ~75° and ~80° available knee and hip flexion, respectively; body habitus not interfering with cycling movement). Burtin et al [16] reported that a single 20-minute cycling session took approximately 30 to 40 minutes (including setup, take-
down, and cleaning). Finally, although our study prospectively identi-

field is needed.

Our study also has several strengths. We had prede

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Fig. 1. Example of patient receiving mechanical ventilation and in-bed cycling in the MICU.
generally occurred on days when patients were receiving mechanical ventilation. In this setting, in prospectively evaluating for 12 safety events during cycling, such events were rare (0.2%; 95% upper confidence interval, 1.0%). Hence, in-bed cycling as part of routine care PT sessions in the ICU appears feasible and safe. Further study of the potential beneficial effects of early in-bed cycling on patient outcomes is needed.

Acknowledgments

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References