

Early Mobilization in the Pediatric Intensive Care Unit: A Systematic Review

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Abstract

Children admitted to the pediatric intensive care unit (PICU) can experience significant morbidity as a consequence of mechanical ventilation and sedative medications. This morbidity could potentially be decreased with the implementation of activities to promote early mobilization during critical illness. The objective of this systematic review is to summarize the current evidence regarding rehabilitation therapies in the PICU and to highlight the knowledge gaps and avenues for future research on early mobilization in the PICU. Using a combination of controlled vocabulary and key word terms, PubMed, CINAHL, and EMBASE databases were searched; no limiters were imposed on search strategies. Two reviewers abstracted data and assessed quality independently. From the 1,928 articles identified in the search, 168 abstracts were identified for full text review. Fifty-nine articles were chosen for data extraction and five were identified for inclusion in review. A sixth article was identified through expert clinician query. The studies were categorized into three groups based on the outcomes discussed: safety and feasibility, functional outcomes, and length of stay. A synthesis of the studies indicates that early rehabilitation in the PICU is safe and feasible with potential short- and long-term benefits. Institutional, provider- and patient-related barriers to initiation of early rehabilitation in the PICU are identified. Recommendations for future investigation include early rehabilitation protocols for children hospitalized in the PICU and identification of outcome measures.

Keywords

- ▶ children
- ▶ critical care
- ▶ early mobilization
- ▶ intensive care
- ▶ pediatric
- ▶ rehabilitation

Introduction

Approximately 250,000 children are admitted to a pediatric intensive care unit (PICU) each year in the United States.¹ The PICU admits critically ill infants, children, and adolescents aged 0 to 18 years with the exception of critically ill newborns who are admitted to the neonatal intensive care unit (NICU). Staff in the PICU provide care for a heterogeneous group of patients with varying chronological ages, developmental stages, and biological needs. Compounding

this heterogeneity, a child may be admitted to the PICU for management of a wide range of medical and surgical diagnoses that includes primary respiratory failure, multi-system organ failure, transplant surgery, congenital heart disease, and trauma. Children with acute exacerbation of chronic disease processes with varying abilities represent a rapidly growing population.² Traditionally, the focus of care in a PICU is on resuscitation, management of critical disease processes, and reversal of organ failure. As a result, critically ill children are often sedated and confined to bed for

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prolonged periods of time due to perceived needs for safety, comfort, and hemodynamic stability.

Many anatomic and physiologic changes are known to occur in response to critical illness, including decreased muscle mass and strength, cardiovascular and pulmonary deconditioning, changes in the inflammatory cascade, alterations in skin integrity, and delirium.^{3,4} These changes may have long-term negative implications on child and family's quality of life.^{5,6} Programs addressing early mobilization and rehabilitation in critically ill adults have been associated with reduced intensive care unit (ICU) and hospital lengths of stay, improved muscle strength, and improved self-perception of functional status.^{7,8} Increased activity and early rehabilitation in the PICU may positively impact the child's recovery from critical illness, but there are limited data specific to the pediatric population to support this hypothesis.⁴

Multiple barriers to the integration of mobilization and rehabilitation in the PICU have been identified. These include a lack of practice guidelines, the need for physician orders, conflicting perceptions regarding safety of and clinical thresholds for early mobilization, and provider knowledge gaps about the benefits of mobilization for critically ill children.^{9,10} The objectives of this study are to summarize the current evidence base regarding rehabilitation therapies in the PICU and highlight knowledge gaps and avenues for future research on early mobilization in the PICU. Acute rehabilitation and early mobilization for the purposes of this review are defined as developmentally age appropriate physical medicine activities undertaken while the child remains hospitalized in the PICU with the intent of increasing physical activity, promoting cognitive recovery, and enhancing developmental growth.

Materials and Methods

Criteria for Selecting Studies

All retrospective and prospective studies investigating acute rehabilitation for children hospitalized in the PICU (ages 1 month to 18 years inclusive) were included. Broad criteria for inclusion were utilized to capture the entire scope of acute rehabilitation studies performed in the PICU. Studies in neonates hospitalized in the NICU were excluded because of the unique developmental needs of the newly born, as well as differences in the NICU and PICU environments. Studies were excluded if they were review articles and/or if the primary objective was to describe a program or protocol designed to promote early mobilization.

Literature Search Methodology

To identify relevant articles, the PubMed, CINAHL, and EMBASE databases were searched. The search strategies were created using a combination of controlled vocabulary and key word terms to define the broad concepts of early rehabilitation and mobility within the ICU setting. No limiters were imposed on search strategies. To capture the greatest number of articles, the search was not limited to "early" rehabilitation. A total of 1,928 articles were identified for review. Each of the titles was reviewed for relevance and

these 168 abstracts were identified for full-text review. Fifty-nine articles were chosen for data extraction and five met criteria for inclusion in the review. Reference lists of the included studies, as well as review articles, were also examined to identify additional studies for inclusion; no additional studies were identified. As a final step, expert clinicians were queried to determine if they were aware of any additional studies that might meet the inclusion criteria; one study was identified.

Results

Six studies were included in the final review (► **Table 1**). The studies were categorized into three groups based on the outcomes discussed: safety and feasibility, functional outcomes, and length of stay. Some studies reported outcomes in more than one category: three studies reported on safety and feasibility, four studies reported on functional outcomes, and two studies reported on length of stay. Study designs included three prospective, two retrospective, and one case report.^{11–16} Randomization occurred in one study.¹⁵

Safety and Feasibility

Of the studies reviewed, three studies reported on data concerning adverse events and feasibility.^{11–13} Abdulsatar et al¹¹ evaluated the safety and feasibility of virtual reality in the PICU, using Nintendo Wii boxing for the virtual reality exercise. They reported no adverse events related to the intervention. Similarly, Hollander et al¹² investigated the safety and feasibility of standardized family-centered inpatient rehabilitation care paths initiated in the PICU for children requiring paracorporeal ventricular assist devices (VAD), and reported no associated adverse events. In a study by Jacobs et al,¹³ children undergoing single-stage laryngo-tracheoplasty, tracheal resection, or cricotracheal resection were assigned to one of two groups based on chronological and developmental age, past medical history, and parental report of the child's ability to cooperate. Children who were judged to be appropriate and able to cooperate with the treatments were allowed graduated liberal activities. The second group of children received standard postoperative treatment interventions (intubation, restraints, sedation with or without neuromuscular blockade). Children assigned to the group who received standard therapy were younger than children assigned to the treatment group. There were significantly fewer reports of atelectasis ($p < 0.001$), post-extubation stridor ($p < 0.001$), or withdrawal syndrome ($p < 0.001$) in the group that allowed liberal activity. There were no significant differences between the groups in the incidence of pneumonia, unplanned extubation, or aspiration.¹³

Functional Outcomes

Because of the substantial heterogeneity in the functional outcome measures presented, the findings from each of the included studies will be discussed. A case report by Schewitz and Van Aswegen¹⁶ reported the outcomes of a child's status after pectus excavatum repair that was mobilized within the

Table 1 Characteristics of included studies

Authors (year)	Study design	Subjects (n)	Age	Patient sample	Rehabilitation intervention	Outcome measures	Results	Notes
Abdulsatar Abdulsatar et al (2013) ¹¹	Prospective	8	3–16 y	<ul style="list-style-type: none"> Anticipated PICU admission > 48 h Normal to moderate cognitive and functional disability 	Nintendo Wii Boxing for 10 minutes at least two times a day for a maximum of 2 d	<ul style="list-style-type: none"> Feasibility and safety Upper body activity, muscle strength, satisfaction 	<ul style="list-style-type: none"> No adverse events Upper body activity ↑ during intervention ($p = 0.049$) No change in grip strength 	<ul style="list-style-type: none"> No correlation between severity of illness score and total playtime 4/8 patients able to participate while mechanically ventilated
Andelic et al (2012) ¹⁴	Prospective quasi-experimental	Intervention: 31 Control: 30	Group A: 27.7 ± 10.9 y Group B: 31.2 ± 11.7 y	Severe TBI	Group A: initiation of early continuous chain rehabilitation in PICU Group B: standard care: therapy after PICU	<ul style="list-style-type: none"> Glasgow Outcome Scale extended 12 mo postinjury: Disability Rating Scale, employment status, living status 	<ul style="list-style-type: none"> Glasgow Outcome Scale extended: Favorable outcome 71% group A and 37% group B ($p = 0.007$). Disability Rating Scale: Better in group A ($p = 0.03$) 	<ul style="list-style-type: none"> Number of patients < 18 y not reported Therapy began at a median of 12 d after injury (interquartile range 8.5)
Hollander et al (2014) ²	Retrospective	< 1 y: 8 > 1 y: 6	0.5–14.4 y	Paracorporeal ventricular assist device	Standardized, age-based, family-centered phased acute rehabilitation for infants (age < 1 y) and children (age > 1 y)	<ul style="list-style-type: none"> Number of phases achieved by each child Safety and feasibility 	<ul style="list-style-type: none"> <1 year: 5/8 achieved all phases. ≥ 1 year: 6/6 achieved all phases. No adverse events related to therapy 	<ul style="list-style-type: none"> 3 children < 1 y did not meet goals secondary to cannula infection, repeated respiratory infections/adult respiratory distress syndrome, or intolerance of handling
Jacobs et al (2001) ¹³	Retrospective	Group A: 54 Group B: 79	Group A: 113 ± 8 mo Group B: 33 ± 3 mo	<ul style="list-style-type: none"> Single stage laryngotracheoplasty, tracheal resection, or cricotracheal resection Developmentally appropriate 	Group A: tracheal intubation, awake, no restraints and liberal physical activity by postoperative day 2 Group B: tracheal intubation with sedation and neuromuscular blockade restraints	<ul style="list-style-type: none"> PICU LOS Hospital LOS Adverse events 	<ul style="list-style-type: none"> PICU LOS ↓ in group A ($p = 0.007$). Hospital LOS ↓ in group A ($p = 0.01$). Group A ↓ adverse events: atelectasis, postextubation stridor, withdrawal syndrome ($p < 0.001$) 	<ul style="list-style-type: none"> Management strategy based on child's chronological and developmental age, past medical history, parents' reports of child's ability to cooperate
Melchers et al (1999) ¹⁵	Prospective experimental	Intervention: 21 Control: 19	3–16 y	Severe TBI	Sensory coma stimulation initiated in PICU (coma duration > 48 h) followed by neuropsychological rehab and psychotherapy interventions after regaining consciousness versus routine treatment and diagnostics	<ul style="list-style-type: none"> Neuropsychological testing Quality of life 	<ul style="list-style-type: none"> Assessment of intelligence/achievement: typical pattern for children with severe TBI. Higher score of intelligence in intervention group at 6 mo with scores at 1 y remaining above average 	<ul style="list-style-type: none"> Reported preliminary results on ~50% of planned sample of 100 children ↑ patients randomly assigned to intervention at the time of reporting with number of follow-ups in intervention

Table 1 (Continued)

Authors (year)	Study design	Subjects (n)	Age	Patient sample	Rehabilitation intervention	Outcome measures	Results	Notes
Schwartz and Van Aswegen (2013) ¹⁶	Case report	1	9 y	Postoperative from elective pectus excavatum repair	Pulmonary toilet and out of bed to chair postoperatively within 0.5 h	<ul style="list-style-type: none"> Prevention of postoperative pulmonary complications Return to normal function 	<ul style="list-style-type: none"> Quality of life results at 6 mo follow-up: children and parents improved ability to manage the sequelae of trauma at 12 mo Remained clear of se- cretions Able to perform most activities of daily liv- ing independently by discharge (postopera- tive day 5) 	<ul style="list-style-type: none"> > control ↑ proportion of se- verely injured ran- domly assigned to intervention

Abbreviations: LOS, length of stay; PICU, pediatric intensive care unit; TBI, traumatic brain injury.

first 30 minutes after surgery in the PICU and received physiotherapy that included pulmonary hygiene and progressive activity. At discharge on postoperative day 5, the child was able to perform most activities of daily living, ascend and descend stairs using a handrail and ambulate 250 m without complaints of dyspnea. They concluded that interdisciplinary rehabilitation was important in the postoperative management of the child with pectus excavatum repair to facilitate an uncomplicated recovery.

In a study by Abdulsatar et al¹¹ involving participation in Nintendo Wii boxing activities for at least 10 minutes twice a day for 2 days in the PICU, effects on upper body activity and muscle strength in children were evaluated. The frequency of upper body activity was significantly greater during the play time ($p = 0.049$), although there was no significant change in grip strength. Hollander et al¹² also reported on functional outcomes in a study of standardized, family-centered acute rehabilitation in the PICU. Children were assigned to one of two groups: younger than 1 year or older than 1 year. The outcome measure was the number of age-specific phases achieved by each child. Eleven of the 14 children achieved all of the goals which ranged from range of motion, participation in play, outings to school, therapy gym, and playroom. Six of the children older than 1 year achieved all phases and three exceeded the set goals. Five of the eight children younger than 1 year met the goals. Reasons presented for not meeting goals included cannula infection, repeated pulmonary infections, and intolerance of handling.

In a prospective quasi-experimental designed study, Andelic et al¹⁴ reported on outcomes in patients who received early continuous chain rehabilitation starting in the ICU versus patients who received standard rehabilitation therapy starting after transfer from the ICU. Continuous chain rehabilitation was defined as early comprehensive rehabilitation started in the ICU and the patient was transferred directly to a rehabilitation facility when medically ready. The patients who received standard therapy did not receive early therapy in the ICU, but received therapy after a waiting period in a local hospital or nursing home or no therapy at all. The patients in this study ranged in age from 16.8 to 42.9 years. Improved global functioning and a favorable outcome assessed by the Glasgow Outcome Scale Extended was found in the group who participated in continuous chain rehabilitation ($p = 0.007$ and $p = 0.003$, respectively). The functioning level, measured by the Disability Rating Scale, was significantly better in the group who received continuous chain rehabilitation ($p = 0.03$). The authors also reported that 39% of the patients in the treatment group were employed full time, part time, or student status as opposed to 27% in the standard therapy group. Eighty-one percent of patients in the treatment group lived at home with or without assistance in contrast to 53% of the patients receiving standard therapy.

Finally, a prospective experimental design study by Melchers et al¹⁵ investigated the impact of PICU-initiated sensory stimulation followed by ongoing neuropsychological rehabilitation and psychotherapeutic interventions in children with severe traumatic brain injury. Preliminary data, reporting on approximately 50% of the planned sample, revealed higher

intelligence scores in the intervention group at 6 months with scores at 1 year remaining above average. Over a 12-month period, the development of nonverbal learning potential indicated that the intervention group benefited from the neuropsychological rehabilitation program. Psychopathological alterations in posttrauma measures supported the effectiveness of the intervention program. Quality of life at the 6-month follow-up demonstrated that the children and parents in the treatment group were better able to manage the sequelae of trauma.

Length of Stay

Two studies reported associations between early mobilization and length of stay.^{12,13} Jacobs et al¹³ demonstrated that children who were allowed liberal activity after airway surgery had a shorter length of PICU stay ($p = 0.007$) and shorter length of hospital stay ($p = 0.01$) than children who were managed with the standard approach of intubation, restraints, and deep sedation.¹³ Hollander et al¹² reported that children who required VAD support while waiting for cardiac transplant surgery who participated in a formal rehabilitation program initiated in the PICU had a PICU duration of stay posttransplant similar to those children who did not require VAD devices pretransplant.

Discussion

A synthesis of the included studies suggests that early mobilization in the PICU is likely safe, and feasible, with potential benefits for short- and long-term outcomes. Nevertheless, several institutional, provider- and patient-based barriers to initiation of early mobilization in critically ill children are apparent, which is similar to the adult literature.⁸ In three recent studies, Choong et al^{9,10,17} identified several of these factors. Institutional barriers to early mobilization included the need for physician orders, insufficient equipment, and a lack of practice guidelines, provider champions, and pediatric sedation protocols. Cited as provider-driven reasons for limited early rehabilitation were safety concerns, conflicting views regarding patient suitability for therapy, poor communication regarding early rehabilitation in the PICU during rounds, and conflicting views regarding patient readiness to participate. Patient-related barriers included medical instability, presence of an endotracheal tube, and risk of device dislodgement.^{9,17}

A survey of the literature regarding early rehabilitation and mobilization in the critically ill adult population reveals several benefits in many areas. These benefits include an improvement in physical functioning, peripheral muscle and respiratory strength, quality of life, decreased rates of delirium, decreased sedation, and a reduction in the number of ventilator days. In addition, early mobilization has been shown to result in a reduction in the ICU and hospital lengths of stay.^{8,18–20}

As this pediatric review establishes, objective evidence in the pediatric population is limited. While not an outcome measure, Hollander et al¹² noted the time to extubation from transplant surgery for children requiring VAD and who

participated in the therapy program to be similar to children who did not require VAD placement pretransplant. This finding suggests that these children approached surgery in a state of physical conditioning that facilitated postoperative recovery and that a structured rehabilitation program initiated during the ICU admission may maintain or improve their level of conditioning. Abdulsatar et al¹¹ did not report a significant increase in grip strength as a result of participating in Nintendo Wii boxing activities, which may be secondary to slow enrollment, narrow patient selection, and timeliness of interventions. A study by Melchers et al¹⁵ measured neuropsychological outcomes impacted by a sensory stimulation for children with severe traumatic brain injury initiated during in the PICU. Only preliminary data were reported, but results indicated an improvement in scores in the treatment group as well as increased quality-of-life markers. With regard to length of stay, Jacobs et al¹³ indicated that children who were allowed liberal activity in contrast to the standard, more restricted activity postoperatively had significantly shorter length of PICU and hospital stays. Although a structured early rehabilitation program was not the intervention in this study, the results indicate that increased activity levels can result in decreased costs and potential decrease in ICU- and hospital-related morbidity, such as nosocomial infections. These findings, while limited by small sample size, are promising for the role of early rehabilitation in the PICU in improving outcomes. The next steps are to continue to identify the barriers to early rehabilitation programs in the PICU setting and to design interventions that will impact the short- and long-term outcomes for this population of children.

Several factors have been found to affect the successful implementation of early rehabilitation programs into the adult critical care setting, including unit culture, early identification of potential barriers, availability of necessary resources, and provider's knowledge and competence.^{8,21} The implementation of an early rehabilitation program in the PICU setting incorporating occupational, physical, and speech therapies requires thoughtful consideration of the same factors. Given the heterogeneous nature of the PICU population, the feasibility of early mobility may be more challenging than the integration of early rehabilitation into the adult ICU setting. The unique anatomical features, the physiologic needs, the chronological and developmental age, and the premorbid functional skills of the child will impact early rehabilitation programs in the PICU setting. A PICU culture that embraces interdisciplinary collaboration is critical to the success of the program.^{22–25} A structured systematic approach to identifying specific facilitators and barriers for a given unit will facilitate the integration of an early rehabilitation program.^{4,8,21,26} Developing rehabilitation programs that stratify patients based on severity of illness and contraindications to therapy has proven successful in the adult ICU population and this same approach with considerations made for the child's chronological and developmental ages in addition to their premorbid functioning will likely prove to be an effective strategy in pediatrics.^{3,4,8,12,13,25}

There are several limitations to this review. With the exception of one study, the sample sizes were small for all included studies.¹³ All of the studies were single-institution experiences, and in the one randomized study included only preliminary and partial data were reported.¹⁵ Abdulsatar et al¹¹ reported slow enrollment and narrow patient selection as barriers to implementation and the study by Melchers et al¹⁵ highlights the barriers to longitudinal studies.

Future Directions

This review has synthesized the available body of evidence regarding early rehabilitation of the critically ill child. Implementation of early rehabilitation is in its infancy in the pediatric critical care arena, leaving the field open to innovation and investigation. Early rehabilitation protocols that stratify children according to severity of illness as well as the understanding of contraindications and limitations to therapy, goal setting, development of therapy teams, and identifying outcome measures are all areas that require further investigation.

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