Enhancing rehabilitation of mechanically ventilated patients in the intensive care unit: A quality improvement project

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ABSTRACT

Purpose: Prolonged periods of mechanical ventilation are associated with significant physical and psychosocial adverse effects. Despite increasing evidence supporting early rehabilitation strategies, uptake and delivery of such interventions in Europe have been variable. The objective of this study was to evaluate the impact of an early and enhanced rehabilitation program for mechanically ventilated patients in a large tertiary referral, mixed-population intensive care unit (ICU).

Method: A new supportive rehabilitation team was created within the ICU in April 2012, with a focus on promoting early and enhanced rehabilitation for patients at high risk for prolonged ICU and hospital stays. Baseline data on all patients invasively ventilated for at least 5 days in the previous 12 months (n = 290) were compared with all patients ventilated for at least 5 days in the 12 months after the introduction of the rehabilitation team (n = 292). The main outcome measures were mobility level at critical care discharge, and this was associated with reduced ICU and hospital LOS and reduced days of mechanical ventilation.

Results: The introduction of the ICU rehabilitation team was associated with a significant increase in mobility at ICU discharge, and this was associated with a significant reduction in ICU LOS (16.9 vs 14.4 days, P = .001), ventilator days (11.7 vs 9.3 days, P < .05), total hospital LOS (35.3 vs 30.1 days, P < .001), and in-hospital mortality (39% vs 28%, P < .05).

Conclusion: A quality improvement strategy to promote early and enhanced rehabilitation within this European ICU improved levels of mobility at critical care discharge, and this was associated with reduced ICU and hospital LOS and reduced days of mechanical ventilation.

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1. Introduction

Advances in critical care have led to increased survival but also the recognition of prolonged physical and psychological morbidity after critical illness. Neuromuscular dysfunction has been identified in up to 46% of intensive care unit (ICU) patients with sepsis, multiorgan failure, or prolonged mechanical ventilation and is associated with longer duration of mechanical ventilation and increase length of ICU and hospital stay [1]. Numerous follow-up studies have shown significant and long-lasting physical and psychological dysfunction in survivors of critical illness [2–4], all of which contribute to a reduced health-related quality of life [5]. In one study, only 49% of survivors of acute respiratory distress syndrome had returned to work at 1 year, and the median 6-minute walk distance was less than 66% of predicted due to global muscle wasting and weakness, foot drop, joint immobility, and dyspnea [6].

Physical, psychological, and emotional dysfunction may persist in patients and caregivers for up to 5 years after discharge from the ICU [6]. Early and structured rehabilitation programs have been shown to be both safe and feasible for critical care populations [7,8]. They have been demonstrated to decrease ICU and hospital LOS [9–12] as well as improve functional ability at the point of hospital discharge [13], with higher levels of mobilization achieved when rehabilitation is led by physiotherapists in comparison with nurses [14]. Early and structured rehabilitation has also been associated with reduced incidence of delirium [13], improvements to respiratory parameters such as a peak inspiration and peak expiration, and improved peripheral muscle strength in comparison with patients who receive no physiotherapy [9].

Although there is a growing evidence base in North American populations, there is a paucity of European-based research into the impact of early rehabilitation programs within critical care, particularly when applied to mechanically ventilated patients. The delivery of physiotherapy within critical care in the United States is very different from that in Europe, with recent US-based studies suggesting that as few as 13% of patients received any physiotherapy within the ICU [10], with treatment provided usually limited to a median of 1 session per patient [11]. This differs from that provided within Europe and Australia.
where daily physiotherapy is already an established standard of care
[15]. It is therefore unclear whether improvements seen in the United
States are applicable to European-based structures and processes of
physiotherapy delivery, or whether it was the similar introduction of
daily physiotherapy and the focus on rehabilitation which was having
a positive impact. A recent point prevalence study in Germany demon-
strated that only 24% of all mechanically ventilated patients and only 8%
of patients with an endotracheal tube were mobilized out of bed as
part of routine care, with only 4% of all patients standing, marching,
or walking [16].

This study evaluates the effects of a quality improvement (QI) pro-
ject involving the introduction of early, structured, and enhanced
physiotherapy-led rehabilitation, commencing when patients were
still mechanically ventilated, in a large UK critical care unit.

2. Materials and methods

2.1. Setting

Queen Elizabeth Hospital Birmingham has a large 75-bed, mixed-depen-
dency critical care unit, admitting more than 3500 patients per
year from all major specialties including general medicine, liver, trau-
ma, burns, neurocritical care, and complex upper gastrointestinal sur-
gery. Prior to the QI initiative, physiotherapy staffing was at a ratio of
1 whole time equivalent to 10 patients. Patients were assessed daily
from Monday to Friday by the physiotherapy team, with treatment ses-
sions lasting on average between 20 and 30 minutes per day with one
physiotherapist. Physiotherapy was provided between the hours of
8 am and 5 pm, with only emergency respiratory on call provision avail-
able outside these hours. Weekend provision was delivered by a signif-
ically reduced service as part of normal weekend working patterns in
the UK, with only very limited rehabilitation available during these
days. Regardless of day of admission, all patients were assessed within
24 hours of admission and received daily physiotherapy within critical
care. Physiotherapy provision was individually prioritized with no set
structure or format for rehabilitation in place. Only limited input took
place if patients were still mechanically ventilated. In terms of other
members of the healthcare team, nursing staffing was at a ratio of 1:1
for ICU (level 3) patients and 1:2 for High Dependency Unit (level 2)
patients. Initiation of rehabilitation and mobilization was led by the
physiotherapists, although after the QI initiative, nursing staff were sub-
sequently involved in mobilizing patients as part of the structured reha-
bilitation plans without the physiotherapists being present. Medical
consultant staffing was at a ratio of 1:12.

2.2. Patients

All patients invasively ventilated for at least 5 days were eligible for
inclusion to the study, but patients were excluded if they had significant
neurologic injury, orthopedic injury with a contraindication to mobilize,
significant burn, or poor preadmission mobility levels (<10 yards) re-
ported by the patients family on admission to the ICU.

2.3. Quality improvement intervention

A new clinical specialist physiotherapist post was created, with a
focus on improving rehabilitation within critical care. The appointed in-
dividual devised the QI intervention, which involved the creation of a
critical care physiotherapy subteam with a focus on rehabilitation,
with additional funding for a senior physiotherapist obtained from the
Queen Elizabeth Hospital Birmingham charity. This subteam directly su-
ervised the physiotherapy sessions for approximately one third of the
patients, but also provided education, support, and advice to the other
physiotherapists working on the ICU and nursing staff. The patients di-
rectly treated by the subteam were chosen according to clinical assess-
ment as to the likelihood of a protracted ICU length of stay (LOS) and
high rehabilitation requirements (eg, those with a diagnosis of ICU ac-
quired weakness). The process of structured critical care rehabilitation
in mechanically ventilated patients adopted by the subteam for the QI
phase has been previously described [17] and is explained in Fig. 1. To
summarize, during the acute phase of a patient’s illness while they
were still sedated and/or paralyzed, rehabilitation was confined to
daily passive movements and positioning (see Fig. 2). Once patients
were physiologically stable and awake enough to commence more ac-
tive mobilization, they were assessed by sitting on the edge of the bed.
Where appropriate, this occurred within the first 5 days of admission
and allowed an assessment to be made of sitting balance, exercise ca-
pacity, and physiological stability. This was performed with endotrache-
al tubes or tracheostomies in situ and while the patient was still on
ventilatory and/or renal support and/or low levels of vasopressor or ino-
tropic support. After this assessment and as strength increased, a reha-
bilitation plan was formulated, which included sitting the patient out of
bed in a chair, using the most appropriate method for transfer (hoist,
board slide, etc.). More active rehabilitation was administered as the pa-
tient improved to progress to standing, transfers, and walking.

To facilitate a seamless and structured approach to rehabilitation, all
patients were assigned a physiotherapy key worker who conducted a
comprehensive assessment of information regarding physical function,
psychological history, and preadmission exercise capacity. This allowed
an individually tailored rehabilitation program to be devised. New
weekly multidisciplinary team meetings were commenced, where a
summary was provided of the patients’ progress and any previously set
goals reviewed and updated. At this meeting, a collaborative treat-
ment plan was generated for the next 7 days by the patients named
key worker. To facilitate ongoing rehabilitation after critical care, both
verbal and written handovers were provided to ward therapy staff
upon discharge from ICU.

2.4. Quality improvement process

The process for improving practice was based on the “4Es” model of
QI—Engage, Educate, Execute, and Evaluate [18]. We engaged and edu-
cated physiotherapy, nursing, and medical staff on the importance and
benefits of early rehabilitation in ventilated patients through individual
bedside training and clinical meetings. The creation of the physiothera-
py subteam with a specific focus and expertise on early rehabilitation
allowed execution of the program. In addition, patient-specific rehabili-
tation plans and goals were transcribed onto wall charts to provide pa-
tients, carers, nursing staff, and the wider multidisciplinary team with a
visible prompt in order to optimize their engagement. As the process
developed, nursing staff became more proactive in helping to sit pa-
tients out and follow the individually tailored programs prescribed by
the physiotherapy team. Weekly multidisciplinary rehabilitation meet-
ings involving physiotherapists, critical care consultants, nursing staff,
and a critical care dietitian discussed progress, barriers, and solutions
throughout the period of QI. These meetings also promoted a collabora-
tive approach to weaning and rehabilitation with consultants and senior
nursing staff.

2.5. Data collection

The QI process was initiated in April 2012 and was evaluated for a
period of 1 year ending March 2013. Retrospective data for the pre-QI
period from April 2011 to March 2012 regarding advanced respiratory
support days, ICU LOS and total hospital LOS, mortality and functional
status were collected from the ICU charts, local physiotherapy docu-
mentation, and hospital electronic databases. Data were collected pro-
spectively throughout the QI period by the lead author. Physical
function was assessed using the Manchester Mobility Score (MMS)
[19] as a measure of daily rehabilitation status within ICU and at ICU dis-
charge. The stages included in the MMS are shown in Fig. 3. This scale,
validated with 120 patients within our mixed population ICU, showed
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excellent interrater reliability between different grades of physiotherapists and nursing staff, with perfect agreement across 3 independent reviewers. The detailed results of the score validation study (reliability and validity) will be presented elsewhere. Demographic data, admission reason, illness severity scores using the Acute Physiology and Chronic Health Evaluation II (APACHE II) scoring system [20], Charlson comorbidity indices and sedation days (defined as >1 hour of sedative infusion in a 24-hour period) were obtained from hospital databases and the electronic prescribing system to assess homogeneity between groups.

2.6. Statistics

Data were analyzed using SPSS v21 statistical software (SPSS, Chicago, Ill). All statistical tests were 2 sided, and significance was determined at the .05 probability level. Length of stay values, sedation days, and advanced respiratory support measures had positively skewed distributions and were logarithmically transformed to produce adequate normal approximations. Simple descriptive summary statistics (percentages for categorical data, mean and SD for normally distributed data, and geometric mean and range for log normally distributed data) were derived. Basic comparisons between groups and outcomes were completed with either a Student t test or Wilcoxon signed ranks test, as appropriate. Subjects who died within ICU were excluded from the outcome comparison but included in the baseline information.

2.7. Ethical considerations

This project constituted an improvement in standard care delivery with no randomization and thus met the definition of a service evaluation under the NHS Health research authority guidelines [21]. As such, ethical approval was not required, and because all outcome measures are collected as part of routine care, the need for consent was waived.

3. Results

All eligible patients who received invasive ventilation for at least at least 5 days on the ICU both prior to and during the QI period were included in the analysis. This represented a sample size of 290 prior to the QI process and 292 after its introduction. Baseline data are provided in Table 1. Patients were well matched in terms of age, sex, admission specialty, and Charlson comorbidity index, although patients in the QI phase had significantly higher illness severity scores on admission to critical care.

The difference in outcomes is summarized in Table 2. After the introduction of the QI intervention, a significant reduction was seen in total

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hospital LOS for patients admitted to critical care and invasively ventilated for at least 5 days (35.3 days pre-QI vs 30.1 days post-QI, \(P = .016\)). Critical care LOS reduced from 16.9 days to 14.4 days (\(P = .007\)), with an associated reduction in ventilator days (11.7 days vs 9.3 days, \(P < .05\)). A slight reduction in sedation days was observed in the QI period, although this was not significant (5.9 days vs 5.2 days, \(P = .12\)). There was no difference in readmission rate to the ICU within the same hospital episode. There was no significant difference observed in terms of critical care mortality between groups, although in-hospital mortality was significantly lower after the introduction of the QI program (39% pre-QI vs 28% post-QI). A regression analysis was performed using APACHE II scores and admission diagnosis, but no correlation was observed for any outcomes (data not shown).

All patients included in the analysis were seen at least once by a physiotherapist, with specific physiotherapy activity information and functional outcomes summarized in Table 3. There were a greater number of treatments per day, with approximately a third of patients seen twice daily within ICU, after the introduction of the QI program. The increased focus on early mobilization led to a significant reduction in hospital stay taken to mobilize (9.3 days vs 6.2 days, \(P < .001\)), defined as achieving an MMS of 2 or more. Manchester Mobility Scores on discharge from the ICU were also significantly higher after the introduction of the QI program, with a median score of 5 indicating that patients were step transferring to a chair at the point of critical care discharge compared with a median score of 3 (hoist transfer to chair) in the pre-QI period.

4. Discussion

There is growing evidence for early and structured rehabilitation within critical care, but implementation of such programs has been variable [17]. Reasons for this include a lack of available funding for physiotherapy posts and a lack of training or experience in delivering such programs [22]. Much of the evidence has been completed in the United States, where standard delivery of physical therapy within critical care is limited. This has limited the transferability to European ICUs, where daily physiotherapy has been a standard of care for a number of years [23], and Australia, where structured rehabilitation programs have so far been unable to demonstrate the same benefit as those seen in the United States [24].

This is the first European-based study examining the effects of an early and structured rehabilitation QI project within critical care for patients mechanically ventilated for more than 5 days. The QI program led to higher levels of mobility at critical care discharge for all patients invasively ventilated for at least 5 days and was associated with significant reduction in ICU and total hospital LOS and shorter periods of mechanical ventilation. These improvements were seen despite higher mean illness severity scores when compared with the control cohort. The reduction in critical care LOS would translate into significant financial benefits, with a 2-day reduction for our cohort of 292 patients representing significant cost savings to the hospital. In actual terms, this would equate to a saving of 584 bed days within critical care, which would have important implications through increasing capacity and availability of beds for new admissions. This was a similar finding to the QI project completed by Needham et al [11], which demonstrated a 20% increase in ICU admissions compared with the previous year.

The introduction of the physiotherapy subteam was part of a wider service improvement project, which included the development of rehabilitation programs. This was implemented across all members of the critical care team. Unlike in other early rehabilitation studies, the emphasis was not focussed specifically on an increase in the number of physiotherapists within ICU, with an

| 1 | In bed interventions (Passive Movements, Active exercise, chair position in bed) |
| 2 | Sit on edge of bed |
| 3 | Hoisted to chair (incl. standing Hoist) |
| 4 | Standing practice |
| 5 | Step transfers with assistance |
| 6 | Mobilising with or without assistance |
| 7 | Mobilising > 30m |

Fig. 2. Exclusion criteria and restrictions to edge sitting.

Fig. 3. Manchester Mobility Score.

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automatic order process for physiotherapy already present before the initiation of the QI process. As such, only modest increases were seen regarding the number of treatments per patient. The emphasis of this project was more focussed on the earlier timing of intervention and the more structured way in which the rehabilitation service was delivered. Physiotherapists are ideally placed to coordinate rehabilitation of patients admitted to critical care [17] as they have advanced skills in respiratory and musculoskeletal assessment coupled with expert knowledge in exercise prescription and progression. They also form a link between laboratory and musculoskeletal assessment coupled with expert knowledge in exercise prescription and progression. The weakness experienced by survivors of critical illness is thought to be multifactorial, including premorbid conditions, ICU acquired weakness, and prolonged bed rest [25].

Muscle mass has been shown to decrease at a rate of between 2% and 4% per day during the first 2 to 3 weeks of ICU admission [26,27], and in some patients, the loss has been reported to be as much as 6% per day [28]. A recent article studying acute muscle wasting in critical illness confirmed that significant muscle mass, as measured by rectus femoris cross-sectional area, is lost during the first 10 days of ICU admission, and that this is likely to be due to increased proteolysis as well as reduced protein synthesis. Furthermore, the extent of organ failure and presence of inflammation correlated with the loss of muscle mass [29]. One small study suggested that the implementation of a mobility protocol within ICU was linked to an increase in IL-10, an anti-inflammatory cytokine [30]. Elucidating the effect of early rehabilitation strategies on muscle atrophy and markers of inflammation is an important area for future research.

We recognize that the before-after design and the lack of blinding of the study team to the outcomes are major weaknesses of our study. The results may be subject to temporal changes and measurement bias. However, there were no other major QI projects or service developments introduced during the study period, and consultant medical and senior nurse staffing were consistent. No changes were made to sedation practice or weaning processes throughout the study period. We believe that improvements seen in both the time taken to mobilize and the MMS at critical care discharge are directly attributable to enhanced rehabilitation. The rehabilitation subteam was only able to directly supervise the treatments of a third of patients. It is not possible to directly assess the impact of these supervised sessions on individual patients, as they were chosen for direct treatment due to predicted high rehabilitation needs. Instead, we believe that the improvement in mobility outcomes demonstrated across all patients is due to an increased awareness of early mobilization and a transformation in culture within the whole ICU. Although no formal measure of preadmission physical function was available with which to compare functional outcomes, we would wish to include this in future trials.

The improvement in hospital mortality is an association that warrants further research, and cannot be directly attributed to enhanced rehabilitation from these data. However, by being less physically dependent on ICU discharge, it is feasible that patients would be less susceptible to further complications during their recovery period. Further work is necessary to confirm our findings and study whether they are reproducible in other ICUs. Although it was not within the remit of this study, future trials should also examine longer-term outcomes including health-related quality of life measures and include a health economics evaluation.

5. Conclusion

We have demonstrated that the introduction of a patient-centered early rehabilitation strategy for patients mechanically ventilated for greater than 5 days improves physical function at ICU discharge. This is associated with a reduction in days of mechanical ventilation and decreased ICU and total hospital LOS.

Authors’ contributions

D.M.: conception and design, introduction of the service improvement project, data collection and analysis, manuscript writing, and final approval of the manuscript. J.W.: conception and design, data collection, and final approval of the manuscript. G.A.: conception and design, data collection, and final approval of the manuscript. J.B.: study design, critical revision, and final approval of the manuscript. J.W.: conception and design, and final approval of the manuscript. C.E.: conception and design, critical revision, manuscript writing, and final approval of the manuscript. T.W.: data analysis, manuscript writing, critical revision, and final approval of the manuscript. C.S.: conception and design, data analysis, manuscript writing, and final approval of the manuscript. All authors read and approved the final manuscript.

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