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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 ICU discharge (assessed via the Manchester Mobility Score), mean ICU, and post-ICU length of stay (LOS), ventilator days, and in-hospital mortality.

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, $P = .007$), 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.

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 increased 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 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,

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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 demonstrated 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) project 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-dependency critical care unit, admitting more than 3500 patients per year from all major specialities including general medicine, liver, trauma, burns, neurocritical care, and complex upper gastrointestinal surgery. 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 sessions 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 available outside these hours. Weekend provision was delivered by a significantly 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 subsequently involved in mobilizing patients as part of the structured rehabilitation 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) reported 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 individual 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 supervised 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 directly treated by the subteam were chosen according to clinical assessment as to the likelihood of a protracted ICU length of stay (LOS) and high rehabilitation requirements (eg, those with a diagnosis of ICU acquired 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 active 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 capacity, and physiological stability. This was performed with endotracheal tubes or tracheostomies in situ and while the patient was still on ventilatory and/or renal support and/or low levels of vasopressor or inotropic support. After this assessment and as strength increased, a rehabilitation 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 patient 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 treatment 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 educated 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 physiotherapy subteam with a specific focus and expertise on early rehabilitation allowed execution of the program. In addition, patient-specific rehabilitation plans and goals were transcribed onto wall charts to provide patients, 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 patients out and follow the individually tailored programs prescribed by the physiotherapy team. Weekly multidisciplinary rehabilitation meetings 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 collaborative 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 documentation, and hospital electronic databases. Data were collected prospectively 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 discharge. The stages included in the MMS are shown in Fig. 3. This scale, validated with 120 patients within our mixed population ICU, showed

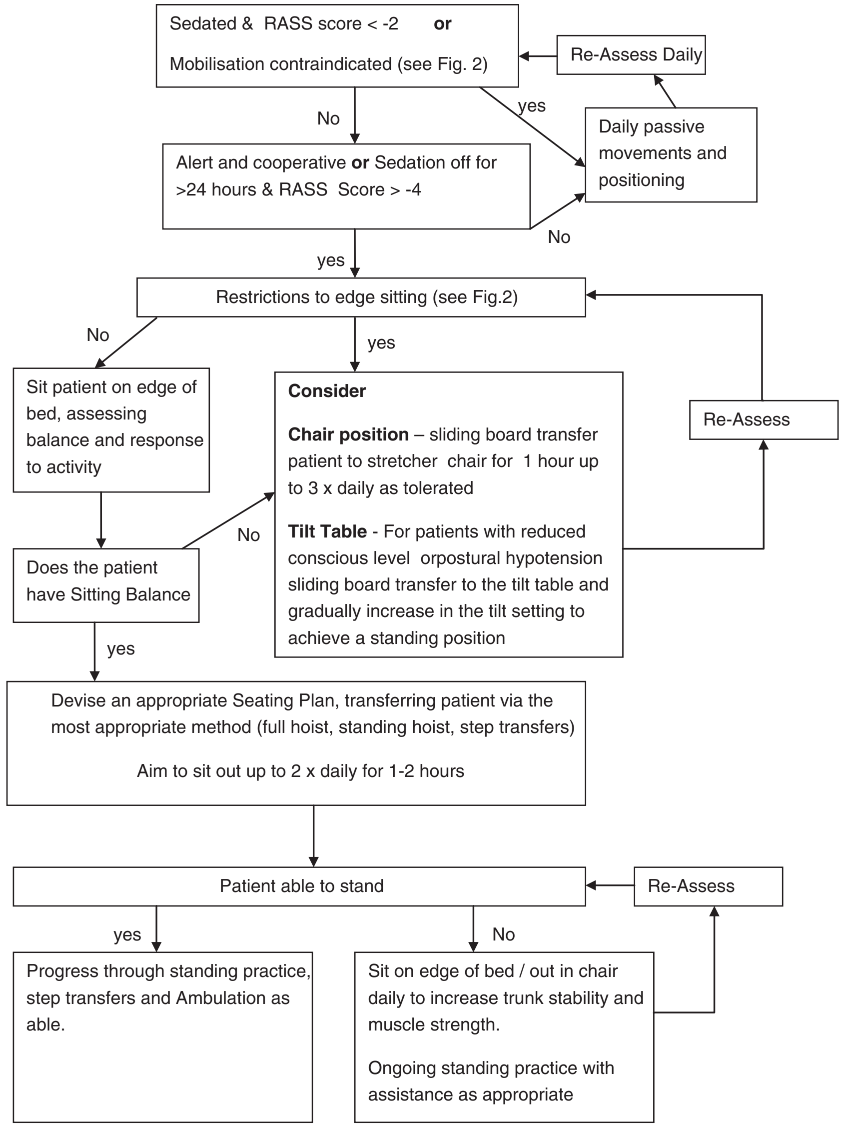

Fig. 1. Early and structured mobility protocol.

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

Exclusion Criteria

- Significant dose of Vasoactive agents (e.g >0.2 mcg/kg/min noradrenaline or equivalent) for haemodynamic stability (Maintain Mean arterial pressure >60)
- Mechanically Ventilated with Fi02 >0.8 and/or PEEP >12 **or** acutely worsening respiratory failure
- Neuromuscular paralysing agent
- Acute Neurological event (e.g CVA, SAH)
- Unstable spine or extremity fractures with contraindications to mobilise
- Active bleeding process

Restrictions to edge sitting

- Small dose of Vasoactive agents (e.g 01 -0.2 mcg/kg/min noradrenaline or equivalent) for haemodynamic stability (Maintain Mean arterial pressure >60)
- Mechanically Ventilated with Fi02 >0.6 and/or PEEP >10
- Poor tolerance of Endotracheal tube
- Open abdomen or high risk for dehiscence – liaise with surgeons prior to mobilising
- Haemofiltration via a femoral line

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

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 time 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 involved education and engagement of 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. 3. Manchester Mobility Score.

Table 1
Baseline data

	Pre-QI	QI phase	
Total number of patients	290	292	
Age (y), median (IQR)	58 (45-69)	55 (44-67)	$P = .24$
Female	117 (40)	111 (38)	$P = .69$
APACHE II score, median (IQR)	16 (13-20)	18 (13-23)	$P < .05$
Charlson Comorbidity Index, median (IQR)	2 (1-4)	2 (1-4)	$P = .45$
Admission diagnosis			
General surgery	77 (26)	67 (23)	
Cardiac	24 (8)	18 (6)	
Neuro	19 (7)	17 (6)	
Respiratory	67 (23)	72 (25)	
Liver	49 (17)	42 (14)	
Trauma	20 (7)	22 (7)	
Other	34 (12)	54 (19)	

Values are n (%) or as otherwise indicated. IQR indicates interquartile range.

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 critical care and the wards to ensure a seamless pathway throughout the patient journey. One significant impact observed was the improved communication in critical care to ensure collaborative weaning plans and to facilitate ongoing daily rehabilitation. Weekly meetings to review progress and set goals for the following week also ensured continued focus on rehabilitation which was essential to ensure continued improvement or new plans to be formulated when progress was slow or restricted.

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.

Table 2
Results

	Pre-QI (n = 202)	QI (n = 225)	*P*
ICU LOS (d)[a]	16.9 (15.4-18.5)	14.4 (13.5-15.4)	.007
Post-ICU LOS (d)[a]	14.5 (12.4-17.1)	12.6 (11.0-14.5)	.197
Total hospital LOS (d)[a]	35.3 (31.9-39.0)	30.1 (27.7-32.8)	.016
Advanced respiratory support days[a]	11.7 (10.7-12.9)	9.3 (8.5-10.2)	.05
Sedation days[a]	5.9 (5.3-6.5)	5.2 (4.8-5.8)	.12
Readmission during same hospital episode	21 (10%)	19 (8%)	.45
ICU mortality	88 (30%)	67 (23%)	.091
In-hospital mortality	114 (39%)	83 (28%)	.028

[a] Geometric means and 95% confidence intervals.

Table 3
Physiotherapy activity levels and physical outcomes

	Pre-QI (n = 202)	QI (n = 225)	*P*
Received physiotherapy within ICU	202 (100%)	225 (100%)	
Total number of physiotherapy treatments	3243	4212	
No. of treatments per day	0.95	1.3	
Time to 1st mobilization (d)*	9.3 (7.8-11.1)	6.2 (5.2-7.5)	.001
MMS on ICU discharge, median (IQR)	3 (2-5)	5 (3-6)	.05

IQR indicates interquartile range.
* Geometric means and 95% confidence intervals.

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 dependant 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.e.: 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.i.: 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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