Journal of Critical Care 44 (2018) 117–123

Contents lists available at ScienceDirect

Journal of Critical Care

journal homepage: www.jccjournal.org

Lumbar skeletal muscle index derived from routine computed tomography exams predict adverse post-extubation outcomes in critically ill patients☆

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ARTICLE INFO

Available online xxxx
Keywords:
Lumbar skeletal muscle index
Extubation
Pneumonia
Adverse discharge disposition
Mortality
Hospital costs

ABSTRACT

Purpose: To evaluate the effect of a skeletal muscle index derived from a routine CT image at the level of vertebral body L3 (L3SMI) on outcomes of extubated patients in the surgical intensive care unit.
Materials and methods: 231 patients of a prospective observational trial (NCT01967056) who had undergone CT within 5 days of extubation were included. L3SMI was computed using semi-automated segmentation. Primary outcomes were pneumonia within 30 days of extubation, adverse discharge disposition and 30-day mortality. Secondary outcomes included re-intubation within 72 h, total hospital costs, ICU length of stay (LOS), post-extubation LOS and total hospital LOS. Outcomes were analyzed using multivariable regression models with a priori-defined covariates height, gender, age, APACHE II score and Charlson Comorbidity Index.
Results: L3SMI was an independent predictor of pneumonia (aOR 0.96; 95% CI 0.941–0.986; $P = 0.002$), adverse discharge disposition (aOR 0.98; 95% CI 0.957–0.999; $P = 0.044$) and 30-day mortality (aOR 0.94; 95% CI 0.890–0.995; $P = 0.033$). L3SMI was significantly lower in re-intubated patients ($P = 0.024$). Secondary analyses suggest that L3SMI is associated with total hospital costs ($P = 0.043$) and LOS post-extubation ($P = 0.048$).
Conclusion: The lumbar skeletal muscle index, derived from routine abdominal CT, is an objective prognostic tool at the time of extubation.

1. Introduction

Low muscle mass is a significant predictor of adverse outcomes in the intensive care unit (ICU), including ventilator-free days, ICU-free days, and mortality [1-3]. To evaluate the patient's physiologic muscle reserve, clinicians rely on clinical bedside tests of muscle strength [4, 5], or subjective judgment, which experienced surgeons refer to as the "eyeball test" [6]. Clinical assessments of muscle strength are volition-dependent and require adequate training of the examiner. Sedation, pain from acute injury, inability to communicate and restriction by medical devices represent additional barriers in the ICU [1]. Imaging allows an objective assessment of muscle mass without the need for patient cooperation [7] and may therefore be better suited for the intensive care setting [2,3,7]. Computed tomography (CT) in particular has been identified as the gold standard for measuring body composition [8-10]. A strong link between muscle cross-sectional area (CSA) at the level of the third lumbar vertebra (L3) and whole-body muscle mass has been established [11]. After normalizing CSA for patients' stature (CSA indexed to height), the resulting skeletal muscle index at the L3-level (L3SMI) is considered a surrogate marker for whole-body muscle mass [12]. Computed tomography (CT) studies are often part of routine clinical care and extraction of muscle CSA from CT images has been found to be highly reproducible [2,13]. Extraction of muscle CSA makes

☆ Results of this study were presented at the "Special Interest Session: High Impact Clinical Trials (SPSI28B)" at the 2016 Radiological Society of North America Annual Meeting.

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https://doi.org/10.1016/j.jcrc.2017.10.033
0883-9441/

use of already-available information without the need for additional radiation exposure or cost.

Various predictors have previously been described for successful extubation and post-extubation outcomes [14-17]. While it is assumed that muscle mass is important for effective physiological ventilation [18-20], the influence of muscle mass on post-extubation outcomes has not yet been investigated.

The aim of this study was to evaluate the effect of a skeletal muscle index derived from a routine CT image at the level of vertebral body L3 (L3SMI) on outcomes of extubated patients in the intensive care unit. We hypothesized that increased L3SMI is associated with a decreased incidence of pneumonia, decreased incidence of adverse discharge disposition, lower 30-day mortality, decreased rate of re-intubation within 72 h, lower total hospital costs, decreased hospital length of stay (LOS) post-extubation, decreased total ICU LOS and decreased total hospital LOS.

2. Materials and methods

2.1. Study design

This HIPAA-compliant secondary analysis of 231 patients of a prospective cohort study (NCT01967056) was approved by the Institutional Review Board of Massachusetts General Hospital (MGH, Boston, MA) (Protocol #: 2015P002617/MGH) and the need for informed consent was waived [21]. Briefly, patients were consecutively enrolled between December 1st, 2012 and January 31st, 2014 in two ICUs at the MGH. Adult patients admitted during the study period were eligible for enrollment if they were intubated and required mechanical ventilation. Patients were included if they were extubated in the ICU. Patients were excluded if they died without an extubation attempt, underwent terminal extubation or tracheostomy without an extubation attempt. Outcomes were collected for 30 days after extubation or until hospital discharge. Only subjects who had undergone a CT examination of the abdomen within 5 days of extubation were included in this analysis since muscle mass can change rapidly in the intensive care setting (Fig. 1) [22].

2.2. Image analysis

Skeletal muscle cross-sectional area (CSA) at the level of the third lumbar vertebral body (L3) was measured on a single axial image using semi-automated, threshold-based segmentation (thresholds −29 and +150 Hounsfield units) [23] in OsiriX Lite (Pixmeo, Bernex, Switzerland) (Fig. 2) [24,25]. A research assistant blinded to all clinical data performed the measurements, which were verified by a board-certified radiologist (8 years of experience). Subjects were excluded only if both the radiologist and research assistant agreed that muscle could not be differentiated from surrounding tissues. Reasons included soft tissue edema ($n = 23$), blood products or posttraumatic disruption of tissue planes ($n = 8$), streak artifact from metallic hardware or limited field of view ($n = 8$). To assess inter- and intra-analyst agreement, 30 images were randomly selected, and then re-analyzed three months later by a second research assistant and by the primary analyst, respectively. Skeletal muscle CSA was divided by height squared to normalize for stature, yielding the L3 Skeletal Muscle Index (L3SMI) in cm^2/m^2 [26], which was gender-adjusted using the multiplicative factor 1.679 for females [7,27]. Subjects without recorded height were excluded ($n = 8$) (Fig. 1).

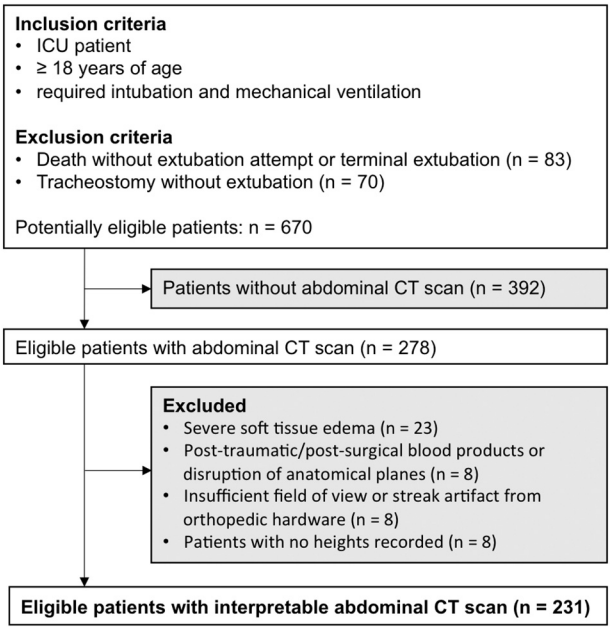

Fig. 1. Consort diagram illustrating the inclusion and exclusion criteria. ICU = Intensive care unit; CT = Computed tomography.

2.3. Clinical data

Age, gender, height, body mass index (BMI), past medical history, Acute Physiology and Chronic Health Evaluation (APACHE) II score on ICU admission [28], Charlson Comorbidity Index (CCI) [29], diagnostic categories upon ICU admission, mortality within 30 days post-extubation, re-intubation within 72 h post-extubation, hospital length of stay (LOS) post-extubation, and total ICU LOS were extracted from study documents and the medical record. Pneumonia within 30 days post-extubation, as well as pulmonary edema, acute respiratory failure and atelectasis within 30 days post-extubation were considered to be present or absent on the basis of international classification of diseases, 9th edition (ICD-9) diagnosis codes.

Data on discharge destination and hospital costs for the entire hospitalization were collected through Enterprise Performance Systems Inc. (EPSi), the performance improvement and financial planning system of Partners HealthCare. Adverse hospital discharge disposition was defined as discharge to a skilled nursing facility (a licensed healthcare

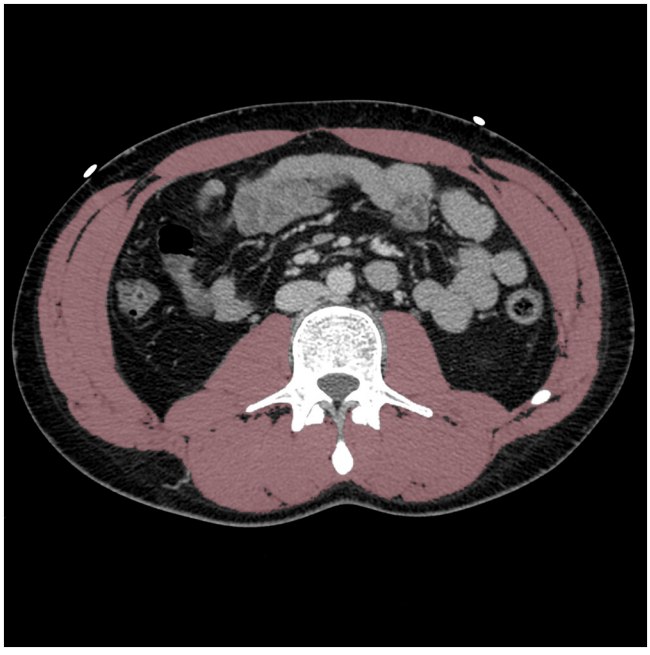

Fig. 2. Semi-automated threshold-based segmentation of muscle cross-sectional area (CSA) at the level of the third lumbar vertebral body. CSA of transversus abdominis, external and internal obliques, rectus abdominis, paraspinal and psoas muscles was computed. This 27-year-old male patient had an Acute Physiology and Chronic Health Evaluation II Score of 27 and a Charlson Comorbidity Index of 0. Muscle CSA was 221.440 cm^2 and patient height was 1.778 m, which resulted in a skeletal muscle index at the level of the third lumbar vertebral body (L3SMI) of 70.05 cm^2/m^2.