Measuring Height in Recumbent Critical Care Patients

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Background  Estimates of the height of patients in the intensive care unit are required to adhere to clinical guidelines for drug dosages, ventilatory support, and nutrition. The gold standard of standing height cannot be used because these patients are often unconscious and recumbent. The ability of physiotherapists or dietitians to measure height in unconscious, recumbent patients has not been evaluated.

Objectives  To compare the accuracy of physicians, physiotherapists, and dietitians in estimating the height of recumbent critical care patients by using existing practice methods.

Methods  A total of 35 patients were recruited from the cardiothoracic preadmission clinic, where standing height is routinely measured by a physiotherapist. After surgery, in the intensive care unit, 1 physician, 2 physiotherapists, and 2 dietitians measured each recumbent patient’s height. Three methods were used: observation, whole-body measurement, and height estimated by using length of the forearm and the British Association for Parenteral and Enteral Nutrition normative chart. Difference from standing height was measured from zero and was compared across professions and methods, with zero indicating no difference.

Results  Overall, 17 physicians, 4 dietitians, and 9 physiotherapists consented to measure patients. After adjustments for method, measurements by physiotherapists did not differ significantly from the gold standard (P = .59), whereas those of physicians (P = .02) and dietitians (P < .001) did.

Conclusions  Physiotherapists’ measurements of supine height of recumbent critical care patients, obtained by using a nonrigid measuring tape, are more accurate than measurements obtained by physicians and dietitians. (American Journal of Critical Care. 2015;24:41-47)
Numerous calculations are required in the intensive care unit (ICU) to adhere to clinical guidelines such as those for drug dosages, ventilatory support, and nutrition. Height estimates are specifically required for calculations of ideal or adjusted body weight and for those involving body surface area, such as cardiac and body mass index. Lung capacity, for example, correlates best with lean body mass, which is a function of height rather than of actual body mass. In a study of estimates of tidal volume, Diacon et al concluded that every ventilator in the ICU should be equipped with a measuring tape to measure height for the prescription of tidal volumes; however, to date no guidelines have been provided on how the height should be measured and by whom.

Standing height is considered the gold standard for accurate measurement of height; self-reported height is second best. Neither of these methods can be used in ICU patients admitted under emergency circumstances who are unconscious and recumbent. Although actual measurement of height is better than visual estimates, questions remain about how accurate the measurements are, the best technique to use, and which personnel are most suitable for obtaining the measurements. In the ICU at Sir Charles Gairdner Hospital, Perth, Australia, according to the usual clinical practice, physiotherapists (for ventilatory reasons) and dietitians (for estimation of nutritional requirements) formally measure height in recumbent patients, and physicians visually estimate height. However, most research on the measurement of height in recumbent ICU or emergency department patients has used physicians and nurses with variable critical care experience, and the accuracy of the measurements has varied. No investigators, to our knowledge, have evaluated the ability of physiotherapists or dietitians to measure height in recumbent ICU patients.

In older patients, measurement of other body segments for estimations of height may be preferable, because these patients may have kyphosis or mobility problems that make accurate standing-height measurement difficult. Forearm length is sometimes used because it is a reliable predictor of height, and is easily obtained in bedfast patients, and, compared with standing height, is less affected by the aging process. The forearm is most accessible in terms of patients’ positioning in the ICU, and only 2 bony landmarks (olecranon and ulnar styloid) are required. The aim of this study was to compare the accuracy of physicians, physiotherapists, and dietitians in estimating the height of recumbent critical care patients by using existing practice methods. The null hypotheses were that physicians, physiotherapists, and dietitians would be able to measure height accurately and that actual measurements would be more accurate than would visual estimates.

**Methods**

**Setting and Patients**

This study took place at Sir Charles Gairdner Hospital, a 600-bed tertiary university hospital where postoperative cardiothoracic patients are routinely transferred to the mixed medical-surgical, 23-bed ICU. Between December 2011 and March 2012, prospective patients for the study were recruited from the cardiothoracic outpatient preadmission clinic, where standing height is routinely measured by the attending senior cardiothoracic physiotherapist. The study had no exclusion criteria; all patients were eligible. Patients were presented with information about the study, and they provided written consent to participate in it. On each patient’s admission to the ICU after surgery, the patient’s attending physician, physiotherapist, and dietitian were also presented with information about the study, and they provided their written consent to participate.
a clinically significant difference of 2 cm, with a conservative estimate of 4 cm for the standard deviation.

**Process**

After surgery, patients were in the ICU resting in bed. During this time they received all usual care. Baseline data, including standing height, age, diagnosis, number of attachments (ie, number of drains, catheters, and leads that might make measurement of height difficult), and estimated time resting in bed when measurements were undertaken, were collected by the principal investigator (D.M.D.), who did not obtain any measurements of height in recumbent patients. Each patient’s height while he or she was recumbent was measured as soon as possible after ICU admission by the patient’s attending physician, 2 physiotherapists, and 2 dietitians. Because this study was a pragmatic one, members of different professions used different methods of measurement according to each member’s usual clinical practice. No additional training related to any of the measurements of height in recumbent patients was provided before data collection.

Patients were not repositioned for measurements, and all measurements were obtained by using a nonrigid measuring tape. All personnel who obtained measurements first estimated the patient’s height on the basis of observation. The attending physician then measured from the top of the patient’s head to the planar surface of the calcaneus (whole body). Dietitians measured forearm length (olecranon tip to tip of ulnar styloid) and then estimated height by using the British Association for Parenteral and Enteral Nutrition normative values, the current clinical practice. Physiotherapists measured height by using both techniques (whole body and forearm length). All measurers had no knowledge of the preadmission standing height and obtained measurements independent of each other.

For the purpose of this study, a difference from zero greater than 2 cm between gold-standard standing height and any other height measurement was considered clinically significant, in line with accurate calculation of body mass index. That is, a difference of more than 2 cm can result in an error in calculating body mass index that will alter the tidal-volume prescription for mechanical ventilation.

**Statistical Power**

The mean difference between standing and supine height estimates in a previous study was 0.73 cm. Power calculations indicated that a sample size of 35 patients would have 80% power to detect a clinically significant difference of 2 cm, with a conservative estimate of 4 cm for the standard deviation.

**Statistical Analysis**

Measurement data were compared with the measurement of standing height obtained by using the gold standard for each patient, and the difference from zero was compared across professions and methods of measurement, with zero indicating no difference. The differences from the gold standard were analyzed by using a linear mixed model. All tests were 2-sided with a significance level of .05.

**Results**

A total of 35 patients consented to be measured in the study, and 17 medical staff, 4 dietitians, and 9 physiotherapists consented to measure patients. No patients were excluded, and none withdrew from the study. The majority of the patients were men (71%), and most of the patients had undergone valve replacement surgery (54%). Demographic and surgical characteristics of the sample are described in Table 1.

All measurements were obtained within 24 hours of ICU admission, and although in most instances the patient remained unconscious and intubated, 6 patients (17%) had become conscious by the time all measurements were completed.

### Table 1

Patient demographic and surgical data (n = 35)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, median (interquartile range), y</td>
<td>65 (60-84)</td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
</tr>
<tr>
<td>≤ 65</td>
<td>18 (51)</td>
</tr>
<tr>
<td>&gt; 65</td>
<td>17 (49)</td>
</tr>
<tr>
<td>Male sex</td>
<td>25 (71)</td>
</tr>
<tr>
<td>Surgery</td>
<td></td>
</tr>
<tr>
<td>Coronary artery bypass grafting</td>
<td>8 (23)</td>
</tr>
<tr>
<td>Valve replacement</td>
<td>19 (54)</td>
</tr>
<tr>
<td>Combination coronary artery bypass grafting and valve replacement</td>
<td>6 (17)</td>
</tr>
<tr>
<td>Other</td>
<td>2 (6)</td>
</tr>
<tr>
<td>No. of attachments at time of first measurement, median (interquartile range)</td>
<td>6 (5-9)</td>
</tr>
<tr>
<td>Endotracheal tube</td>
<td>33 (94)</td>
</tr>
<tr>
<td>Central venous catheter</td>
<td>35 (100)</td>
</tr>
<tr>
<td>Arterial catheter</td>
<td>35 (100)</td>
</tr>
<tr>
<td>Balloon pump</td>
<td>3 (9)</td>
</tr>
<tr>
<td>Electrocardiographic leads</td>
<td>35 (100)</td>
</tr>
<tr>
<td>Indwelling catheter</td>
<td>35 (100)</td>
</tr>
<tr>
<td>Pacing wires</td>
<td>12 (34)</td>
</tr>
<tr>
<td>Pulmonary artery sheath</td>
<td>17 (49)</td>
</tr>
<tr>
<td>Femoral catheter</td>
<td>4 (11)</td>
</tr>
</tbody>
</table>

*Data are No. (%) of patients unless indicated otherwise.*
Overall the measurements differed significantly between professions (Table 2). Measurements obtained by physiotherapists did not differ significantly from the gold standard ($P = .59$), whereas those of physicians ($P = .02$) and dietitians ($P < .001$) did.

A comparison of the measurement methods for each profession (Table 3) indicated that the difference between the measurements obtained by observation and those obtained by using the gold standard was smallest for physiotherapists (0.14 cm lower, $P = .86$) but did not not differ significantly from either the whole-body measurement or measurements based on the forearm length. For the physicians, the difference between the whole-body method and the gold standard did not differ significantly from zero (1.05 cm higher, $P = .38$); however, the difference from zero between the observed method and the gold standard was significant (2.61 cm higher, $P = .03$). Although these differences did not differ significantly from each other, the difference from zero between the observed method and the gold standard did not exceed the difference that is considered clinically significant. Within the dietitians, the differences between measurements based on the length of the forearm and measurements obtained by using the gold standard were significantly different from zero (2.54 cm higher $P < .001$), as were differences between measurements based on observation and those obtained by using the gold standard (3.23 cm higher, $P = .008$). Neither of these differences from zero matched the difference that is considered clinically significant.

When patients were stratified by age ($\leq 65$ years and $>65$ years; Table 4), for the younger age group, the differences between the measurements and the gold standard did not differ significantly from zero for the physiotherapists (0.38 cm lower, $P = .73$) or the physicians (0.43 cm higher, $P = .74$). However, the corresponding difference for dietitians was significant (2.35 cm higher, $P = .04$). In addition, when the differences from the gold standard were considered, neither physiotherapists and physitians ($P = .42$) nor dietitians and physicians ($P = .08$) differed from each other, but physiotherapists differed from dietitians ($P = .001$).

Overall in the older group, for physiotherapists, differences between the measurements and the gold standard did not differ significantly from zero (1.16 cm higher, $P = .13$), whereas differences from zero were significant for physiitians (3.56 cm higher, $P < .001$) and dietitians (3.46 cm higher, $P < .001$). In addition, both physiotherapists and physicians ($P = .02$) and physiotherapists and dietitians ($P = .005$) differed significantly from each other, but physicians did not differ from dietitians ($P = .92$).

Table 5 indicates which method of measurement was best for each profession when measurements were stratified for age. Physiotherapists had no significant difference between methods for the younger cohort ($P = .07$). Differences between the measurements obtained by using the gold standard and those obtained by using the other 3 methods were not significant; however, whole-body measurements had the smallest difference (0.49 cm lower). In the older cohort, differences between the 3 methods were not significant ($P = .32$), and none of the 3 methods produced measurements that differed significantly from measurements obtained by using the gold standard. The whole-body measurements had the smallest difference (0.16 cm).
Physician's measurements of the younger cohort were equally accurate for the observation method and the whole-body method ($P = .19$). However, measurements obtained by using the whole-body method differed the least from measurements obtained by using the gold standard (0.74 cm lower). In the older cohort, the difference between the observation method and the gold standard was significantly different from zero (4.16 cm; $P = .02$). The difference between the whole-body method and the gold standard was not significantly different from zero ($P = .09$), but the estimated mean difference did exceed the difference that is considered clinically significant (2.94 cm).

For dietitians, in the younger cohort, the differences from zero between measurements obtained by using the gold standard and those obtained by using the other 2 methods were significant, but the measurements obtained by the other methods did not differ from each other ($P = .89$). Even so, the mean difference between the observation method and the gold standard was the closest to zero (2.28 cm). In the older cohort, measurements obtained by using the observation method and by using the forearm-length method differed significantly from measurements obtained by using the gold-standard method. The observation method had a 4.24-cm ($P = .002$) difference from the gold standard, which was not statistically different from the 2.68-cm ($P = .04$) difference between the forearm method and the gold-standard method.

All measurements by any of the caregivers obtained by using any method were within 11.5% of the standing-height measurement (Table 6). Overall, the mean percentage difference from the gold standard was 2.95%; measurements obtained by the physiotherapists had the smallest percentage difference (2.71%) from the gold standard.

**Discussion**

The main aim of this study was to compare the accuracy of physicians, physiotherapists, and dietitians in estimating height in recumbent patients by using existing practice methods. We found that physiotherapists were most consistently able to measure recumbent height closest to the gold-standard standing height and with lower standard error for any technique and across both age cohorts. Further, measurements obtained by the physiotherapists had the lowest estimated mean difference in both age groups of patients when the whole-body method was used. These findings are perhaps not surprising. The undergraduate training of physiotherapists includes studies of body-surface anatomy, anthropomorphic measurements, and range of movement. Although physicians receive similar training, they are perhaps less practiced in true objective clinical measurement and arguably more likely to estimate height. Dietitians have limited training in body-surface anatomy and anthropomorphic measurements. Anecdotally, in our ICU dietitians measure height only when no one else has already done so and nutritional requirements must be estimated. Although statistically measurements obtained by dietitians had the largest differences from zero, in a clinical sense, larger measurement errors may be acceptable when used for a nutritional prescription. A difference in height of up to 4 cm corresponds to a difference of approximately 24 cal/d when the Pennsylvania State (Mifflin) 2003 equation, the standard energy calculation in our ICU, is used. This difference would lead to a change in feeding rate of only 1 mL/h in a continuous 2-hour standard feeding regimen.

Overall, in terms of which method of measurement was the most reliable, the whole-body method...
was better than the observation method for both physiotherapists and physicians. Whether dietitians would also be most accurate when using this method was beyond the scope of the study and could be explored in the future.

The difficulty in measuring any supine patient may be compounded in the ICU by the presence of numerous attachments (eg, ventilator circuits, drains, monitoring cables). Our cohort of patients who had cardiac surgery may not have reflected the general ICU population for predictability of course and length of stay, but the patients had a high number of attachments. The impact of the number of attachments on individual measurers is unknown. Although all the measurers worked in the ICU during the study period, no data were collected about their ICU experience. Perhaps some measurers or professional groups were more comfortable moving and manipulating attachments, and that ease might have influenced both the ability to measure and the accuracy of the measurement.

Despite these attachments, and despite professional differences already alluded to, all measurements were within 11.5% of those obtained by using the gold-standard method, and the overall mean difference from zero was 2.95%. These results reflect greater accuracy by our measurer cohort, particularly physiotherapists, than the accuracy reported elsewhere. Our results are also well within the 20% difference that Coe et al reported would give rise to clinically significant errors.

Whatever the method, the measurement tool may also be important. In a recent Australian study, a rigid 3-m metal measuring tape combined with a head board and a foot board (bookend method) was used. Although it was specifically designed for that study, most likely the device is nonconforming and relies on having the patient lie flat and potentially be repositioned for measurement in order to standardize alignment of body parts and body positioning. We prefer a nonrigid conforming measuring tape used by personnel specifically trained in surface anatomy and measurement.

Limitations

All measurers were recruited on the day of measurement as the staff in each profession allocated to look after the patients on that day. Thus, although our results were significant, we had access to only a relatively small number of dietitians in the measurer cohort. The unequal number of individual measurers per specialty may have introduced a bias, whereby one dietitian who was particularly inaccurate in his or her measurements may have unduly influenced the overall accuracy of measurements obtained by dietitians as a group. Conversely, because a larger number of medical staff obtained measurements, estimations of height by this group may have most accurately reflected the accuracy of the population of physicians as a whole.

No data were collected on the number of times individual measurers were asked to measure a patient, potentiating measurement “practice” or “training” whereby informed measurers might improve as the study continued. This potential training effect was minimized by providing no feedback to the measurers about their accuracy after each measurement was obtained.

The ability of nursing staff to measure height was not assessed because measuring height is not a normal clinical practice in our ICU. This factor may limit the extent to which our results can be extrapolated to other units where nurses do measure height.

Conclusion

Physiotherapists’ measurements of the supine height of recumbent ICU patients obtained by using a nonrigid measuring tape are more accurate than measurements obtained by physicians and dietitians. This difference may reflect the undergraduate training of physiotherapists in body-surface anatomy, anthropomorphic measurements, and range of movement. However, in the context of clinically meaningful difference, the larger measurement errors in the dietitian group may be acceptable in nutritional prescription.

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FINANCIAL DISCLOSURES

None reported.

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