Brief Communication

Height measurement in the critically ill patient: A tall order in the critical care unit

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Abstract

Height measurement in the critical care unit is necessary for estimating ideal body weight and providing titrated patient care. In this study, we compare three methods of height assessment and evaluate their level of correlation and inter-observer reproducibility. Heights of 100 consecutive patients were assessed independently by two nurses by supine, four point, and arm span methods. Paired sample *t*-test, one-way analysis of variance, Tukey's honestly significant difference *post-hoc* analysis and Bland–Altman plots were performed to assess agreement between measurements. Arm span method showed higher mean height compared to supine and four point methods. Mean heights derived by supine and four point measurements were similar to each other but were significantly different from that of arm span method ($P < 0.001$). Inter-observer correlation of the measured heights was very good among all three methods. The supine method seems to be easy, accurate, and reproducible in our study.

Keywords: Arm span measurement, critically ill patients, four point measurement, height, height measurement, supine measurement

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Introduction

Height measurement is an essential component of the assessment of the critically ill patient. Several important decisions in the treatment of critically ill patients such as tidal volume settings,[1] drug dosing,[2] and calculation of nutritional goals[3] rely on accurate measurement of height. Obesity which is determined by body mass index is an important predictor of mortality in the critically ill patient.[4] Height is a required measurement for calculating this parameter.

However, accurate height is not easy to measure in the critical care setting. With the patients in the supine position and many times attached to several lines and tubes, obtaining an accurate height is almost impossible. Therefore, visual estimations of patients' heights were popularly used.[5] However, studies have shown that such visual estimations are often inaccurate[2] and therefore, alternative methods have been recommended and practiced. The Chumlea method uses a length of the lower leg to calculate the height of the patient.[6] Another method used a formula incorporating forearm length to estimate the height.[7] Several other methods using demi-span, arm span, half-arm span and knee length have been described in the literature.[8] Presently, there is no consensus on the best method to measure height in a critically ill patient.

There is a need to identify an easy, practical, reliable, and accurate method of measuring height in critically ill

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patients in order to appropriately prescribe and modify various interventions. This study aimed to compare the reliability of three methods of measurement of height in critically ill patients namely the supine length measurement, four point height estimation, and arm span method.

Methods

Study setting and sample

The study was conducted in a medical-surgical critical care unit (CCU) of a tertiary care private hospital in Chennai, India. To estimate a 50% prevalence of inaccurate height measurement by any one method, for a 10% precision and 95% confidence level the sample size was calculated as 100. Hundred consecutive patients admitted to the CCU between December 2012, and February 2013 were recruited for the study.

Study methods and measurements

Two nurses, who were blinded to each other's measurements, independently measured the height of each of the 100 patients admitted to the CCU. They used three methods to measure the height.

- Supine length measurement: The patient was made to lie down supine. Using a flexible measuring tape the length between the vertex of the head and the heel was measured. The measurement was taken up to one decimal point. Although this measure is easy to do, it may be unreliable in patients with joint contractures
- Four point method of measurement: Serial measurements from vortex of head to medial end of clavicle, lateral aspect of shoulder to anterior superior iliac spine, anterior superior iliac spine to lateral aspect of knee joint, and lateral aspect of knee joint to sole of foot were obtained and then added together to obtain the patient's height. This method although cumbersome and can potentially lead to errors, is not altered by joint contractures
- Arm span measurement: With the patients' arms horizontal and in line with the shoulders the length between the middle of the sternal notch and tip of either middle finger was measured and added up. Height was calculated using the standard formula (1.35 × arm span + 60.1) for females and (1.40 × arm span + 57.8) for males, respectively.[9]

Statistical analysis

Paired sample *t*-test was performed to assess agreement between the two nurses in all the three measurements. One-way analysis of variance (ANOVA) was performed to assess for statistically significant differences in means of the three measurements. Tukey's honestly significant difference (Tukey's HSD) *post-hoc* analysis was done to identify the measurements which agree and those which did not. The Bland–Altman plot was performed for the tests which showed agreement in the *post-hoc* analysis to further represent the mean difference in the measurement and the limits of agreement.

Results

Of the 100 patients who were studied 64% were men and the rest women. The mean age of the patients studied was 56.8 ± 17.9. The nurses who performed the measurements were holding a bachelor's degree in nursing and had at least 2 years of experience in the CCU.

There was strong agreement between the two nurses in all the three measurements as indicated by the paired sample *t*-test results shown in Table 1. The mean heights of patients measured by nurses 1 and 2 were 162.75 ± 9.26 and 162.8 ± 9.03 by supine method (P = 0.93), 164.04 ± 9.1 and 164.82 ± 10.45 by four point method (P = 0.29) and 170.03 ± 8.3 and 169.83 ± 8.17 by arm span method (P = 0.73).

The mean height as measured by the nurses using the three methods shows that the arm span method shows higher mean height compared to the other two methods [Figure 1]. One-way ANOVA of the three methods of height measurement revealed that the three methods were different statistically [Table 2]. The Tukey's HSD revealed that the mean difference between supine method arm span method and four point method - arm span method were significantly high (P < 0.001 for both), whereas the difference between supine – four point methods were not significant [Table 3].

As the supine height measurement and the four point method showed agreement, their Bland–Altman curve was plotted to assess their mean difference and limits of agreement in a pictorial form [Figure 2].

Discussion

Height measurement, which remains a tall order in the critical care setting, plays a very vital role

Table 1: Inter-rater agreement in the measurements

Method	Mean±SD (cm)		P (paired t-test)
	Nurse 1	Nurse 2	
Supine method	162.75±9.262	162.8±9.039	0.929
Four point method	164.04±9.108	164.82±10.455	0.285
Arm span method	170.03±8.311	169.83±8.179	0.729

SD: Standard deviation

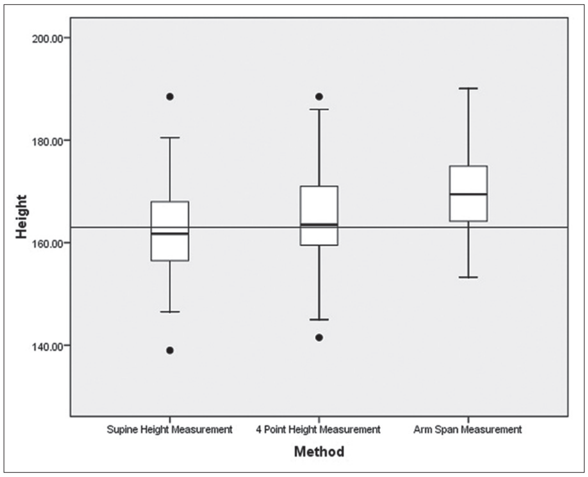

Figure 1: Box plot of height measurements using the three different methods used in the critical care unit. The arm span method shows higher mean height compared to the other two methods

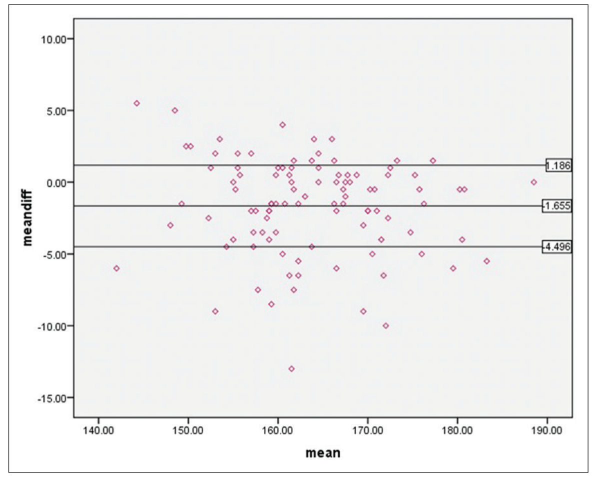

Figure 2: Bland–Altman curve to assess mean difference and limits of agreement. The mean difference between the two measurements is −1.655, and the limits of agreement are between −4.496 and 1.186, thus indicating a fairly good agreement

Table 2: Comparison of the three methods of height measurement

Method	Mean height	SD	SEM
Supine height measurement	162.7	8.7	0.871
Four point method of height measurement	164.4	9.1	0.910
Arm span method	169.9	7.7	0.770

Between groups sum of squares: 2806.313, within groups sum of squares: 21,605.393, F: 19.289, $P<0.001$. SD: Standard deviation; SEM: Standard error of mean

Table 3: Mean differences between the three methods - *post hoc* analysis

Method	Supine height measurement	Four point method of height measurement	Arm span method
Supine height measurement	-	1.655 ($P=0.357$)	7.155 ($P<0.001$)*
Four point method of height measurement	1.655 ($P=0.357$)	-	5.5 ($P<0.001$)*
Arm span method	7.155 ($P<0.001$)*	5.5 ($P<0.001$)*	-

*$P<0.001$

in calculating various parameters crucial for the provision of care. This study measured heights of 100 consecutive patients in a tertiary hospital critical care setting. The inter-rater variability between two critical care nurses was observed to be negligible. Further, it was found that the supine measurement and the four point method had a fair agreement with a difference of about 1.655 cm between the two methods. However, the arm span method deviated significantly from both the supine and the four point methods.

A previous study showed that arm span was not a reliable method of height assessment among people of African and Asian ethnicity.[9] This study also showed significant deviations of the arm span height from the height measurements done by other methods. This emphasizes the importance of standardizing height measurement methods unique for Asian Indians.

The importance of measurement of height in the critical care setting has been well described. However, practically feasible methods to measure the height remain a challenge. The three methods tested in this study, namely the supine, four point and the arm span method are simple and easy to apply procedures. They can easily be performed even in supine and bedridden patients.

It is important to point out here that while this study did show that there is good agreement between the supine and the four point methods of height measurement and poor agreement with the arm span method, it does not validate any of these methods against the gold standard of standing height measurement using a stadiometer. However, it does give us pointers as to the probable poor applicability of the arm span method due to its wide disagreement with the other two methods. The other important point of discussion is whether the 7.155 cm difference between supine and arm span method and the 5.5 cm difference between the four point and arm span method are clinically significant or not. From a purely nutrition point of view, the formula used for calculating the basal metabolic rate (BMR) for a patient is BMR = 10 × weight (kg) + 6.25 × height (cm) – 5 × age (y) + 5 for males and BMR = 10 × weight (kg) + 6.25 × height (cm) – 5 × age (y) − 161 for females.[10] This BMR is multiplied by a factor based on activity levels to calculate the caloric requirement of the patient. It is evident here that a

1 cm error in height measurement will contribute a 6.25 units difference in the caloric calculation. Thus, even small differences in estimation of height can contribute to a 6 times gross under or over estimation of the caloric requirement.

Conclusion

Accurate height measurement in the critical care setting is important. This study showed that the supine method and the four point method show a strong agreement compared to the arm span method. We, therefore, propose that the supine or four point method be used in Asian Intensive Care Units. Thus, future research should focus on the supine method and four point method and standardize and validate them for regular use in the critical care setting. Future validation of either of these methods with the gold standard standing method with stadiometer in volunteers is warranted.

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Conflicts of interest

There are no conflicts of interest.

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