Using ulnar length to estimate height in undifferentiated adult emergency department patients

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Abstract

The dose of critical medicines or ventilator settings should not be a guessing game. Yet in the emergency setting, dosing that relies on ideal body weight (IBW) is difficult logistically in a helicopter or a busy trauma bay and often relies on a simple visual estimate to determine the patient's height, and thus IBW. There have been previous studies showing a relationship between the length of a patient's ulna and their height, but these were mostly in the pediatric pulmonology literature. We measured patients' ulna length and height in a convenience sample of undifferentiated adult Emergency Department patients in order to make a linear regression with best-fit line equation for this population. After easily measuring the patient's arm, the emergency provider can then plug the length into our equation to calculate height and then IBW. Our whole cohort equation is $y = 3.5852x + 74.908$, with a correlation coefficient of 0.7109 and an $R^2$ value of 0.5054. This study suggests that with one quick and easy measurement life-saving medicine doses and ventilator settings can more accurately be determined.

Introduction

Critically ill patients requiring invasive ventilation are often encountered in the pre-hospital and Emergency Department setting. It is important that providers across the entire emergency care spectrum aim to adopt strategies that emphasize lung protective ventilation. Additionally, these patients may require vasoactive medications, sedatives, or paralytics. While many of these medications are typically dosed based on total body weight (TBW), many medicine are best dosed by IBW.

Frequently, providers are met with the challenge of obtaining accurate height and weight measurements, either due to an austere setting or simply being in a crowded resuscitation bay. In practice, it is common for providers to use visual estimate for height and weight either out of convenience or if the required tools for measurement are unavailable.

To date, several studies have described using surrogate measurements to estimate standing height in both adult and pediatric populations.\textsuperscript{1,2,3} For example, anthropomorphic data used for height estimate has been collected in various forms including: arm span length, lower leg length, mid-upper arm circumference, forearm/ulnar length, sitting height, waist circumference, upper arm length. A number of these studies collected data in primarily homogenous populations. In this study, we aim to obtain data from a varied population of patients presenting to our adult emergency department.

The purpose of this study was to obtain a set of anthropomorphic data points from which we could derive a formula to predict height. We chose ulnar length as it is an easy to obtain measurement whether in the confined space of a transport vehicle or when multiple providers are surrounding the patient. After analyzing the data through use of scatter plots and linear regression, we aimed to derive a formula to estimate standing height from ulna length.

Should a strong correlation exist between ulna length and height in our population, a formula would allow us to predict height from a simple measure of ulna length. In clinical practice, this could provide
emergency providers a more accurate means of obtaining height versus visual estimate. In turn, (IBW) could be calculated from this height estimate for the purposes previously discussed including lung protective ventilation strategies and medication dosing.

Methods

Study Enrollment

This was a prospective observational study utilizing a convenience sample of patients presenting to our adult emergency department. Data for this study was obtained primarily during the initial emergency department triage process. After being triaged, patients were provided with a brief introduction to the study, and if interested, they were consented and guided through the full purpose, design, and implications of the research. Inclusion criteria for the study were any patient presenting to our adult emergency department with at least one forearm for ulna measurement and ability to stand to have height measurement taken.

Data Collection

Patients’ ulna length was measured with retractable tape measure. Measurement occurred from the posterior aspect of the olecranon to the ulnar styloid process in the wrist. Patients were instructed to hold their arm up in a position of 90° flexion at shoulder and elbow toward the data collector.

Participants were then asked to stand against a wall tape measure to gather height. Additionally, patients were asked to estimate their own height measurement which was also recorded. All recordings were done in centimeters though patient estimated height was typically provided in feet/inches and then converted to metric. Patients were asked to remove shoes for height measurement though many participants declined due to various reasons such as limited mobility or convenience.

Data was collected on intake sheet and later uploaded to an excel file. Demographic information was also collected including patient age, gender, identified race.

We gathered demographic and anthropomorphic data on 200 patients. We ultimately removed one patient from analysis due to having a measured ulnar length more than two times the standard deviation from the mean, while his height was within two times the standard deviation from the mean, suggesting an error in data recording. Thus, we analyzed the data from 199 patients.

Statistical Analysis

Data was arranged in 15 different groups by gender and age at a number of different cutoffs as follows: whole cohort, all females, all males, age ≤ 49, males ≤ 49, females ≤ 49, age ≥ 50, males ≥ 50, females ≥ 50, age ≤ 59, males ≤ 59, females ≤ 59, age ≥ 60, males ≥ 60, females ≥ 60. Ulna length and height
were plotted on scatter plot for each group and linear regression with best-fit line equations were generated. Pearson correlation coefficient and $R^2$ value were calculated for each regression. Statistical significance was set at a $p$ value $< 0.05$.

**Results**

Characteristics of the cohort are available in Table 1. Of the various groups, the subgroup of all patients aged $\geq 60$ provided an equation with the best accuracy statistics, followed by the equation derived from the whole cohort, which was closely followed by the equation derived from all patients aged $\leq 59$. The equation for the whole cohort is $y = 3.5852x + 74.908$, with the measured ulnar length (in centimeters) input as variable $x$, which will then provide an estimated height. This equation has a correlation coefficient of 0.7109 and an $R^2$ value of 0.5054, both of which have a $p$-value of $<0.001$. The equations, correlation coefficients, and $R^2$ values of all age/sex subgroups are provided in Table 2. The $p$-values for all correlation coefficients and $R^2$ values are $<0.001$ with only two exceptions: sex-specific equations for patients $\geq 60$. These values for males $\geq 60$ are still statistically significant, leaving only the equation for females $\geq 60$ failing to achieve statistical significance.

<table>
<thead>
<tr>
<th>Table 1. Demographics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td><strong>Race</strong></td>
</tr>
<tr>
<td>Caucasian</td>
</tr>
<tr>
<td>African American</td>
</tr>
<tr>
<td>Hispanic</td>
</tr>
<tr>
<td>Mixed</td>
</tr>
<tr>
<td>Asian</td>
</tr>
</tbody>
</table>
Table 2. Equations and Statistics

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Equation</th>
<th>R value</th>
<th>R² value</th>
<th>p-values*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole cohort</td>
<td>199</td>
<td>y = 3.5852x + 74.908</td>
<td>0.7109</td>
<td>0.5054</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>All females</td>
<td>104</td>
<td>y = 2.7061x + 95.387</td>
<td>0.5752</td>
<td>0.3308</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>All males</td>
<td>95</td>
<td>y = 2.6723x + 102.39</td>
<td>0.5373</td>
<td>0.2887</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>All ≤49</td>
<td>132</td>
<td>y = 3.4636x + 78.329</td>
<td>0.6933</td>
<td>0.4806</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>All ≥50</td>
<td>67</td>
<td>y = 3.8421x + 67.739</td>
<td>0.7482</td>
<td>0.5598</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Females ≤49</td>
<td>73</td>
<td>y = 2.471x + 101.95</td>
<td>0.5727</td>
<td>0.328</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Males ≤49</td>
<td>59</td>
<td>y = 2.9101x + 96.019</td>
<td>0.5195</td>
<td>0.2698</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Females ≥50</td>
<td>31</td>
<td>y = 3.4158x + 76.195</td>
<td>0.5798</td>
<td>0.3362</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Males ≥50</td>
<td>36</td>
<td>y = 2.2835x + 112.71</td>
<td>0.5884</td>
<td>0.3463</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>All ≤59</td>
<td>169</td>
<td>y = 3.5645x + 75.664</td>
<td>0.7078</td>
<td>0.501</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>All ≥60</td>
<td>30</td>
<td>y = 3.6762x + 71.348</td>
<td>0.7321</td>
<td>0.536</td>
<td>&lt;0.001</td>
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<tr>
<td>Females ≤59</td>
<td>92</td>
<td>y = 2.5897x + 98.708</td>
<td>0.5823</td>
<td>0.3391</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Males ≤59</td>
<td>77</td>
<td>y = 2.7868x + 99.572</td>
<td>0.5198</td>
<td>0.2702</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Females ≥60</td>
<td>12</td>
<td>y = 3.8311x + 64.493</td>
<td>0.5098</td>
<td>0.2599</td>
<td>0.09</td>
</tr>
<tr>
<td>Males ≥60</td>
<td>18</td>
<td>y = 2.102x + 116.48</td>
<td>0.643</td>
<td>0.4134</td>
<td>0.004</td>
</tr>
</tbody>
</table>

*in all cases, p-values for R and R² were the same

Discussion

Based on the data from this study, a correlation exists between ulna length and height that is statistically significant, though the exact correlation falls into the fair to moderate range based on correlation coefficients. This correlation is strongest in patients aged greater than 60 and when all groups (both males/females, all ages) are scored together with a correlation, but does lose some statistical significance with both males and females over 60 years of age. This is possibly secondary to expected height loss that occurs with age. Chen’s results in 2017, which studied both children and adults, did have a substantial correlation coefficient greater than 0.8 when comparing arm span length and ulnar length with standing height. This stronger association may be a result of a population of convenience as we suspect many of the adults measured were parents of the enrolled children as the average age of adult participants was in the low to mid 30s. Additionally, this study did not evaluate non-Taiwanese
populations or participants over 64 years of age. It has previously been noted that variations exist amongst different ethnic groups and when comparing pediatrics versus adults as well. Several studies have previously investigated similar measurements to assess for correlation with standing height— including leg length, arm span, sitting height, but this has previous been used for primary predictors of nutrition, medication administration, pulmonary function. Based on our review of the literature, there has not previously been a study focused on the efficient measurement of ulna length for assessment of ideal body weight in the emergency setting. Intubation and mechanical ventilation are commonly performed procedures in the emergency department and in the prehospital environment. The etiology of the need for ventilation is vast and decisions regarding ventilator settings must be made in a relatively urgent manner and be patient-specific. Specifically, tidal volume is a variable that should be well controlled in order to prevent significant barotrauma and iatrogenic lung injury. Per the ARDS Network trial, lower tidal volumes of 6mL/kg showed improved survival rates. Tidal volume, which is the amount of air that moves in or out of the lungs with each respiratory cycle, is traditionally based on ideal body weight rather than true body weight. IBW is calculated based on height alone. Just following intubation in the emergency department or in the prehospital setting, the patient’s height is typically not easily obtainable in a timely fashion and frequently visual estimates are utilized. By formulating an equation that would allow for swift and more accurate estimation of height, it is our hope that the most appropriate ventilator settings could be utilized as early as possible.

This study has several limitations. First and foremost, one of the strongest limitations of our study was the ability to recruit participants. Data was collected from patients, staff, and visitors in a busy emergency department. For example, many people were approached regarding participation, but were unwilling to participate due to their ailments or the burden of the consent process. Second, there also was some inconsistency regarding whether participants’ heights were measured with or without shoes. With every participant, the effort was made for shoes to be removed, but many were unable to do this secondary to the logistical issues of being in a crowded emergency department. Third, data was gathered in an un-blinded manner from a convenience sample of patients, both of which have inherent limitations. Finally, as the purpose of this study was to derive a formula from undifferentiated ED patients, we did not actually test whether this method is more accurate than visual estimates.

Moving forward, our group hopes to obtain additional data regarding the accuracy of the visual estimates of nursing, EMS, and physician staff of a patient’s height compared with the ulnar length estimate and the patient’s measured actual height. We hope to show that measuring ulnar length will provide a more accurate estimate of height than other estimates, primarily visual, and that its ease and practicality for a single provider will lead to real-world use when other methods of measuring a patient’s height tend to be neglected.

**Declarations**

**Ethics Statement**
This study was approved by the institutional review board of The University of Tennessee College of Medicine, Chattanooga campus (study number 20-057). This study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki.

Consent to Participate

Written informed consent was obtained from all participants and from a parent and/or legal guardian.

Consent for publication Written informed consent was obtained from the patient for publication of this study and accompanying images.

Competing Interests

The authors declare that they have no competing interests

Authors' contributions

Study concept and design: FT, JS; Data collection: DS, JS, DG, KS, VJ; Analysis and interpretation of results: FT, DS, KS, DG; Draft manuscript: FT, DS, KS, TC; All authors reviewed the results, read, and approved the final version of the manuscript.

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Availability of data and materials

All data analyzed in this study are included in the published article

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Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Rawdataulnalenlength.xlsx