Lung protective mechanical ventilation
Wolthuis, E.K.

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Chapter 3

Reliability of Height and Weight Estimates in Patients Acutely Admitted to Intensive Care Units

Rogier M. Determann*, Esther K. Wolthuis*, Peter E. Spronk, Michael A. Kuiper, Johanna C. Korevaar, Margreeth B. Vroom and Marcus J. Schultz

*These authors contributed equally to this study

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Abstract

**Background:** To determine the accuracy of estimated height and weight values of acutely admitted intensive care unit (ICU)–patients.

**Design and setting:** Prospective multicenter study in one academic and two non–academic ICUs on height and weight estimated by nurses directly on admission (estimated height and weight). These data were compared with measured height (actual height) as well as height and weight provided by patients or relatives (provided height and weight).

**Patients:** Three hundred consecutive acutely admitted ICU–patients from whom preadmission height and weight were unknown to health care workers.

**Results:** Estimated and provided height agreed well with actual height. Mean differences with actual height were small: 2.2 ± 0.4 cm and 0.4 ± 0.2 cm, with 95%–limits of agreement from −9.9 to 14.3 cm and −5.0 to 5.9 cm, respectively. Mean difference between estimated and provided weight was also small: 0.8 ± 0.5 kg, with 95%–limits of agreement from -15.1 to 16.7 kg. Height was consistently overestimated in the shortest patients. Actual height did not influence estimation of height and weight, but estimation of weight was more variable in patients with higher body mass index (BMI). BMI calculated from estimated height and weight agreed well with BMI calculated from measured height and provided weight, although several patients fell into the wrong BMI–subgroup when using estimated instead of measured and/or provided in calculating patients’ BMI.

**Conclusion:** Estimated height and weight values are reliable values in the ICU. However, especially in shorter patients misestimation may have important consequences. BMI values differ importantly, depending on whether they are calculated from estimated or provided data.
Introduction

Height and weight of patients are mandatory for daily practice in the intensive care unit (ICU). In patients with acute lung injury and in patients with acute respiratory distress syndrome it is presently advised to adjust tidal volumes to the predicted bodyweight (which is a function of height) [1-3]. Secondly, patients’ weight is used to adjust the dose of many drugs, and infusion of vasoactive drugs is expressed as microgram per kilogram (kg) bodyweight per minute to assess cardiovascular function and to make comparisons between patients possible [4]. In addition, recent studies have investigated obesity as a risk factor for additional morbidity and mortality in critically ill patients [5-11].

Unfortunately, obtaining patients’ height and weight can be difficult. ICU–patients are often unable to inform caregivers of their actual height and weight. Although patients’ height can be easily measured by means of a tape measure, in our institutions height is not measured but estimated by the attending nurse. Alternatively, height and weight values can be obtained from patients’ relatives, but it is questionable how precise they recall these values. Furthermore, although weight can be measured by using special beds, it is unsure whether the measured weight of acutely admitted patients truly reflects their preadmission weight. Indeed, patients in shock may require early infusion of large amounts of fluids leading to increased weights prior to admission to the ICU [12].

The present study analyzed whether estimated height is in agreement with measured height and whether height and weight estimated by nurses are in agreement with height and weight given by patients and/or relatives. We determined the influence of patients’ actual height and body mass index (BMI) on these estimated values. In addition, we investigated whether BMI values calculated from estimated height and weight values are in agreement with BMI values calculated from measured height and weight provided by patients’ relatives.

Methods

Population

Data from consecutive acutely admitted ICU–patients from whom preadmission height and weight values were unknown were prospectively collected. On admission the nurse registered patients’ height and weight into the patient data management system (PDMS; Metavision, iMDsoft, Sassenheim, the Netherlands). For inclusion in our study, the registered values had to be estimated. If the values could be obtained from previous medical charts, the patient was excluded from the analysis. Estimation of height and weight was done by eyeballing while the patient was lying horizontally. In addition, the closest relatives (spouses or children) were asked for preadmission height and weight and height was determined with a tape measure by the researcher. Scales to weigh patients
were not routinely available in our institutions. As acutely admitted patients often require substantial amounts of fluid we choose not to weigh our patients. We reasoned that weight provided by relatives would be a better estimate of patients’ preadmission weight. The protocol was in accordance with the ethical standards of local ethical committees for the protection of human subjects; informed consent was not deemed necessary because of the observational nature of this study, and because the study did not modify diagnostic or therapeutic strategies.

**Institutions**

The ICU of the Academic Medical Center (AMC) is a 28–bed mixed “closed format” (patient care is directed by critical care specialists) department, in which medical/surgical patients (including cardiothoracic and neurosurgical patients) are treated. In the Gelre Hospitals (location Lukas, GH), an affiliated teaching hospital, the ICU is a 10–bed “closed format” mixed medical/surgical department (excluding cardiothoracic surgery and neurosurgery). The Medical Center Leeuwarden (MCL), a large general teaching hospital in the north of the Netherlands, has a 17–bed “closed format” mixed ICU (excluding neurosurgery).

**Definitions**

- Actual height: height measured with a tape measure.
- Provided height: height asked from patients’ relatives.
- Estimated height: height estimated by nurses directly on admission.
- Provided weight: weight asked from patients’ relatives.
- Estimated weight: weight estimated by nurses directly on admission.
- Actual BMI: BMI calculated from actual height and provided weight.
- Provided BMI: BMI calculated from provided height and weight by the patient or relatives.
- Estimated BMI: BMI calculated from estimated height and weight.

**Statistics**

Mean differences between actual height values and provided and estimated height values, between provided and estimated weight values and between actual BMI and provided and estimated BMI were calculated. Mean difference was used to assess bias of estimating methods. The 95% limits of agreement were calculated to assess agreement between estimating and asking or measuring methods for individual patients. The 95% limits of agreement are defined as the mean difference ± 2 standard deviation (SD) for normally
distributed data and as the limits comprising 95% of all data for non-normally distributed data [13]. Bland–Altman plots were created to display the individual data on the magnitude of the differences between two different definitions of height, weight of BMI. The middle horizontal line displays the mean difference. The two outer lines display the limits of agreement. Finally, to investigate whether estimation was poorer/better in patients with more extreme height or BMI patients were divided into four actual BMI groups and four actual height groups. Differences between these subgroups were evaluated with the Kruskal-Wallis test. Absolute data are expressed as means ± standard deviation; mean differences are expressed as means ± standard error. p < 0.05 was considered statistically significant. All statistical analyses were performed using SPSS 12.0.2.

**Results**

**Data collection**

In each hospital one hundred patients were included. Height was measured in all 300 patients. Provided height was not obtained in six patients and provided weight not available in seven. From three patients, estimated height was not available. Estimation of weight was obtained for all patients. There were no significant differences in missing data between the three hospitals.

**Differences between the various height values**

Mean actual height was 171.4 ± 10.1 cm (figure 1). Mean provided height was 172.0 ± 10.0 cm. Mean estimated height was 173.5 ± 9.9 cm. Mean difference between provided height and actual height was 0.4 ± 0.2 cm (p = 0.006). The 95% limits of agreement were –5.0 to 5.9 cm. Mean difference between estimated height and actual height was 2.2 ± 0.4 cm (p < 0.001). The 95%–limits of agreement were –9.9 to 14.3 cm. The majority of all estimated values (96 percent) were within 10 percent of the measured values. Moreover, also 96 percent of the estimated values was within 10 percent of the provided values.

**Differences between the various weight values**

Mean provided weight was 77.7 ± 15.1 kg (figure 1). Mean estimated weight was 78.3 ± 16.3 kg. Mean difference between provided weight and estimated weight was 0.9 ± 0.5 kg (p = 0.044). The 95%-limits of agreement were –14.7 to 16.5 kg. In contrast to estimated height values, only 75 percent of the estimated weight values were within 10 percent of the provided values.
Figure 1 (a) Scatter plot of height provided by patient and/or relatives (provided height) against measured height (actual height); (b) height estimated by nurses (estimated height) against actual height; (c) weight estimated by nurses (estimated weight) against weight provided by patient and/or relatives (provided weight). In all graphs (a-c) the diagonal line represents the line of equality; (d) Bland-Altman plot of differences between actual height and provided height against the mean of these methods; (e) differences between actual height and estimated height; (f) differences between provided and estimated weight. In all graphs (d-f) the middle horizontal line represents the mean difference; the outer two horizontal lines represent the 95%-limits of agreement.

Differences between BMI values

Mean actual BMI was 26.4 ± 4.6 kg/m². Mean provided and estimated BMI were 26.3 ± 4.6 kg/m² and 26.0 ± 4.7 kg/m², respectively (figure 2). Mean difference between actual and provided BMI was −0.1 ± 0.1 kg/m² (p = 0.011). The 95%-limits of agreement were −1.8 to 1.6 kg/m². Mean difference between actual and estimated BMI was −0.4 ± 0.2 kg/m² (p = 0.018). The 95%-limits of agreement were −6.4 to 5.6 kg/m². When patients were divided into BMI groups several patients fell into another group when using estimated instead of measured and/or provided values for height and weight in calculating patients’ BMI (table 1).
Figure 2 (a) Scatter plot of body mass index (BMI) calculated from measured height and weight provided by patient (pt) and/or relatives (actual BMI) against BMI calculated from height and weight provided by pt and/or relatives (provided BMI); (b) actual BMI against BMI calculated from height and weight estimated by nurses (estimated BMI). In both graphs the diagonal line represents the line of equality; (c) Bland-Altman plot of differences between actual BMI and provided BMI against the mean of both methods; (d) differences between actual BMI and estimated BMI. In both graphs the middle horizontal line represents the mean difference; the outer two horizontal lines represent the 95%-limits of agreement.

Table 1 Number of patients in BMI groups: BMI based on actual height and provided weight vs. BMI on estimates of those values

<table>
<thead>
<tr>
<th>Estimated BMI&lt;sup&gt;a&lt;/sup&gt;</th>
<th>&lt;20</th>
<th>20-24.9</th>
<th>25-29.9</th>
<th>≥30</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20</td>
<td>7</td>
<td>9</td>
<td>67</td>
<td>43</td>
</tr>
<tr>
<td>20-24.9</td>
<td>9</td>
<td>67</td>
<td>43</td>
<td>3</td>
</tr>
<tr>
<td>25-29.9</td>
<td>0</td>
<td>17</td>
<td>77</td>
<td>17</td>
</tr>
<tr>
<td>≥30</td>
<td>0</td>
<td>14</td>
<td>25</td>
<td>0</td>
</tr>
</tbody>
</table>

<sup>a</sup>For 11 patients, either actual BMI (weight in kilograms by height in meters squared) or estimated BMI could not be calculated because of missing values of height and/or weight.
Influence of actual height and actual BMI on estimating height and weight

Weight of patients with a low BMI was overestimated while weight of patients with a high BMI was more likely to be underestimated. Moreover, height was increasingly overestimated with increasing BMI. The 95%–limits of agreement for estimation of both height and weight were much wider in the highest BMI groups (Table 2). Estimation of height was significantly poorer in the lowest height group compared with the other groups (p < 0.001). Height was consistently overestimated in the lowest height group compared with the other groups and the 95%–limits of agreement between estimated and actual height were much wider for this height group (Table 3).

### Table 2 Influence of actual BMI on estimations of height and weight

<table>
<thead>
<tr>
<th>Difference</th>
<th>&lt; 20 (n = 16)</th>
<th>20–24.9 (n = 96)</th>
<th>25–29.9 (n = 134)</th>
<th>≥ 30 (n = 46)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between actual and provided or estimated height, cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual height, mean (SD)</td>
<td>172 (12)</td>
<td>172 (10)</td>
<td>172 (9)</td>
<td>172 (10)</td>
</tr>
<tr>
<td>Provided height minus actual height, mean (SE)</td>
<td>-0.9 (0.5)</td>
<td>-0.1 (0.3)</td>
<td>0.8 (0.2)</td>
<td>0.5 (0.4)</td>
</tr>
<tr>
<td>95% limits of agreement</td>
<td>-3.2 to 5.1</td>
<td>-5.5 to 5.3</td>
<td>-5.0 to 6.5</td>
<td>-4.3 to 5.3</td>
</tr>
<tr>
<td>Estimated height minus actual height, mean (SE)</td>
<td>-0.9 (1.5)</td>
<td>0.7 (0.5)</td>
<td>2.7 (0.5)</td>
<td>5.0 (1.1)</td>
</tr>
<tr>
<td>95% limits of agreement</td>
<td>-13.0 to 11.3</td>
<td>-8.8 to 10.1</td>
<td>-9.2 to 14.6</td>
<td>-10.3 to 20.4</td>
</tr>
</tbody>
</table>

| Between provided and estimated weight, kg | | | | |
| Provided weight, mean (SD) | 56 (8) | 69 (9) | 80 (9) | 97 (18) |
| Estimated weight minus provided weight, mean (SE) | 4.5 (1.4) | 1.0 (0.6) | 1.2 (0.6) | -1.6 (1.8) |
| 95% limits of agreement | -6.6 to 15.6 | -10.7 to 12.8 | -12.9 to 15.4 | -26.2 to 23.0 |

### Table 3 Influence of actual height on estimations of height and weight

<table>
<thead>
<tr>
<th>Difference</th>
<th>&lt; 165 (n = 71)</th>
<th>165–174 (n=110)</th>
<th>175–184 (n=95)</th>
<th>≥ 185 (n = 24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between actual and provided or estimated height, cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual height, mean (SE)</td>
<td>158 (5)</td>
<td>170 (3)</td>
<td>179 (3)</td>
<td>189 (5)</td>
</tr>
<tr>
<td>Provided height minus actual height, mean (SE)</td>
<td>1.0 (0.4)</td>
<td>0.1 (0.2)</td>
<td>0.4 (0.3)</td>
<td>0.2 (0.5)</td>
</tr>
<tr>
<td>95% limits of agreement</td>
<td>-6.0 to 7.9</td>
<td>-4.6 to 4.9</td>
<td>-4.5 to 5.4</td>
<td>-4.9 to 5.3</td>
</tr>
<tr>
<td>Estimated height minus actual height, mean (SE)</td>
<td>4.9 (0.9)</td>
<td>2.2 (0.5)</td>
<td>1.3 (0.5)</td>
<td>-2.5 (1.0)</td>
</tr>
<tr>
<td>95% limits of agreement</td>
<td>-10.0 to 19.8</td>
<td>-8.2 to 12.6</td>
<td>-8.8 to 11.4</td>
<td>-12.5 to 7.3</td>
</tr>
</tbody>
</table>

| Between provided and estimated weight, kg | | | | |
| Provided weight, mean (SD) | 69 (14) | 76 (11) | 83 (16) | 90 (13) |
| Estimated weight minus provided weight, mean (SE) | 2.1 (1.1) | 0.2 (0.6) | 0.7 (0.9) | 1.5 (1.7) |
| 95% limits of agreement | -15.7 to 19.8 | -12.6 to 13.1 | -16.0 to 17.4 | -14.9 to 17.9 |

### Discussion

In the present study we found that height and weight estimated by nurses are in general adequate values, although misestimations for height and weight were as large as 15 cm and 15 kg respectively. We found that estimation of height was more accurate than estimation of weight. This is in line with an earlier report on estimated height and weight values in critically ill patients [14]. We found that patients with the lowest BMI were more likely to have an overestimated body weight whereas patients with the highest BMI were
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underestimated. Moreover, height was consistently overestimated in the shortest patients. BMI calculated from estimated height and weight values and BMI calculated from measured height and provided weight values agreed well. However, several patients fell into the wrong BMI subgroup when using estimated instead of measured and/or provided values in calculating patients’ BMI.

**Limitations**

Several flaws of the present study must be mentioned. First, it is unknown what proportion of the data from the nurse records was truly estimated. It might be that relatives provided height and weight on admission to the ICU. However, we suggest this only happened in a minority of cases, since the use of the PDMS requires the input of height and weight directly on admission and relatives are usually not present at the bedside at that moment. Also, in the GH, weight and height had to be entered into a local database, from which dosing tables for vasoactive medication were calculated. In the MCL, height and weight were recorded in a database used for collecting data used for the NICE (Netherlands IC Evaluation) [15].

Second, we did not measure patients’ weight, and assumed that weight provided by patients or their relatives would be a better estimate of patients’ preadmission weight than measured values since acutely admitted patients may have received substantial amounts of fluids prior to transfer to the ICU. This may be an important drawback, since it is questionable how well patients and relatives can recall a patients’ weight. Additional studies are needed to address this issue.

Third, measuring height with a tape measure in a supine patient may result in different height values than measuring height in a standing position [16]. This bias can not be avoided in critically ill patients, however.

Fourth, increased awareness by our personnel of the importance of height in applying lung–protective mechanical ventilation may have led to an improvement of nurses’ skill in estimating patients’ height [17]. Therefore, our data may not be easily translated to other institutions.

**Clinical relevance**

The clinical relevance of misestimating height and weight may not be the same for all patients. This can be illustrated with some simple examples. A female patient with an actual height of 160 cm has an ideal body weight of 52.4 kg (when using the equation, ideal body weight = 45.5 + 0.91[height (in cm) − 152.4]) [18]. Adjusting tidal volumes to 6 ml/kg, means that ideal tidal volumes in this particular patient should be close to 300 ml. Overestimation of height by 14 cm (the higher end of the 95% limits of agreement) results in a rise of her tidal volume of approximately 80 ml, which is roughly 25% of her ideal tidal
volume. By contrast for a female patient with an actual height of 185 cm the tidal volume adjusted to 6 ml/kg must be close to 450 ml. Overestimation of height by 14 cm also results in a rise of her tidal volume of 80 ml, which is only 17% of her ideal tidal volume. The same arguing applies for overestimation of weight which may lead to higher medication doses. We found a systematic overestimation of height occurring most in the shorter patients. We did not find a systematic overestimation for weight but the range of limits of agreement was large. Systematic overestimation in shorter patients has been described before by Coe et al. but was not found by Leary et al. [16,19]. It is questionable whether increases in tidal volume or medication dose as a consequence of overestimation of height and weight are clinically relevant. In small people however, it may be important to realize this effect.

**Body mass index**

Not surprisingly, we found a fairly good relation between actual BMI and provided BMI. For the purpose of this study, actual BMI was calculated from actual height and provided weight, while provided BMI was calculated from provided height and weight values. With a good correlation between actual and provided height, these two calculated BMI-values, per definition, will have a good correlation. For the calculation of estimated BMI, we used estimated height and weight values. In general, estimated BMI and actual BMI agreed well. The relevance of misestimations of 5 kg/m² or more depends on what the BMI is used for. If patients are divided into various BMI groups for analysis of patient outcome, patients may fall into the wrong BMI-group if using estimated BMI (table 1). In this case estimation of BMI may lead to misleading results.

**Conclusions**

We conclude that estimation of height, weight and BMI by nurses is adequate in general. Height is generally better estimated than weight. Overestimation of height occurred particularly in the shortest patients while overestimation of weight occurred especially in patients with a low BMI. The consequences of misestimation depend on what height, weight and BMI are used for. Especially in shorter patients the consequences of misestimation should be realized. BMI values differ importantly, depending on whether they are calculated from estimated or provided data.
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