# The Accuracy of Visual Estimation of Body Weight in the ED

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**Preventable medical errors may be due to incorrect drug dosage based on poor weight estimation. This study was to examine the accuracy of patient weight estimations in an emergency medical setting. This prospective study enrolled a convenience sample of medically stable adults. The patient's attending physician, resident physician, nurse, a paramedic, and the patient estimated the patient's weight. Of 394 patients enrolled, patients erred in the estimation of their weight by greater than 20% only 1.5% of the time. The group values were 14.7% for attending physicians, 13.4% for resident physicians, 15.9% for nurses, and 17.4% for paramedics. Our study suggests that emergency department staff estimation of a patient's weight is often inaccurate. When available, the patient's own estimate can be used as their actual weight. When the patient is incapacitated, measurement of the patient's weight is the proven method to avoid this type of dosage error. (Am J Emerg Med 2004;22:526-529. © 2004 Elsevier Inc. All rights reserved.)**

Error is an inevitable occurrence in medical practice. The Institute of Medicine (IOM) report "To Err Is Human" estimates between 44,000 and 98,000 patients hospitalized each year die as a result of medical errors.[1] Many of these errors are due to medication errors. In the Harvard Medical Practice study performed in New York State, 19% of adverse events were attributable to medication errors, predominately the ordering and delivery of medication.[2] Errors may be reduced with the retrieval and delivery of medications using computer-assisted drug delivery systems like the Pyxis. However, dosage errors can also occur when medications are ordered or prescriptions written. In an examination of 2,213 prescriptions written by house staff in a California pediatric emergency department (ED), Wingert found that 33% contained dosing errors.[3] According to Lesar et al, incorrect dosage accounts for 15% of all errors of medication ordering.[4]

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In the ED, patients frequently arrive unconscious or otherwise incapacitated and an accurate weight measurement can be difficult to obtain. Medication dosages are often based on estimation of the patient's weight. An overestimation of the patient's weight will increase the calculated dosage and may result in potentially life-threatening side effects. An underestimation will result in a lower dosage that may not provide the patient with therapeutic concentrations of the medication.

The significance of weight and its estimation has been examined in the pediatric population where weight-based dosing is central to pediatric practice. Despite the frequent use of weight-based dosing, physicians, nurses, and parents are unable to consistently and accurately estimate pediatric weights.[5,6] Measuring the child's weight before any medications are given is the current standard of care for this population.[5]

Incorrect weight estimation can also affect adult emergency department patients. Heparin is an example of a weight-based medication commonly used in the ED for adults. Heparin's therapeutic window is relatively narrow. An underestimation of the patient's weight yields too low a dose for pharmacologic effectiveness, resulting in insufficient anticoagulation. An overestimation resulting in too high a dose yields bleeding that can be life-threatening.[7,8] Other examples of weight-based dosing include thrombolytics, paralytics, steroids, sedatives, and some antimicrobials.

Although weight-based dosing is used in the adult population, patients are not consistently weighed. Most estimates are based upon the supposition that the average male weight is 70 kg. The practioner then increases or decreases the dose based on how much the practitioner believes the patient deviates from 70 kg. The ability of practitioners to accurately estimate a patient's weight has not been studied in the adult ED population.

The goal of this study was to examine the accuracy and the degree of error of adult weight estimation by emergency medical personnel.

## MATERIALS AND METHODS

This prospective study enrolled by convenience sample. Institutional Review Board approval was obtained for this study.

Medically stable patients above 17 years old were enrolled at an academic tertiary care ED over a 2-month period. Informed consent was obtained. Patients were not approached if they were medically unstable, did not speak English, or were a prisoner. Patients that refused to participate were excluded.

**TABLE 1.** Deviation From the Patient's Actual Weight

| | Number of Patients (N) | Mean Deviation (Estimate-Actual) | 95% Confidence Interval of Mean Deviation | |
|---|---|---|---|---|
| Patient | 392 | 0.46 | 0.04 | 0.89 |
| Attending | 292 | −4.85 | −6.15 | −3.55 |
| Resident | 343 | −4.03 | −5.28 | −2.78 |
| Paramedic | 144 | −1.39 | −3.39 | 0.60 |
| Nurse | 383 | −3.85 | −5.09 | −2.60 |

**TABLE 3.** Correlation Coefficient

| | Number of Patients (N) | Correlation Coefficient (r) | Statistical Significance (*P*) |
|---|---|---|---|
| Patient | 392 | 0.98 | <.0001 |
| Attending | 292 | 0.83 | <.0001 |
| Resident | 343 | 0.81 | <.0001 |
| Paramedic | 144 | 0.79 | <.0001 |
| Nurse | 383 | 0.78 | <.0001 |

Research assistants were instructed in the use of the digital scale, inclusion, and exclusion criteria, and the blinding of the study. Research assistants approached eligible patient between the hours of 9 AM until 1 AM during the study period. Consenting patients were asked to estimate their weight. The research assistant using a portable digital scale, zeroed before use, then weighed the patient. Patient demographic information was collected. Patients were asked not to reveal their weight to the staff. Next, the patient's attending physician, resident physician, nurse, and a paramedic estimated the patient's weight. Each participant was taken into the patient's room individually to give their estimation. Personnel were not given feedback on the accuracy of their weight estimation, to inhibit feedback learning.

Weight estimations were accepted in either pounds or kilograms. Any estimation given in pounds was converted to kilogram by one of the investigators (B.A.). The ED staff was informed of the study before its initiation.

Deviations from the actual weight were recorded as positive if above the actual weight and negative if below. The data were evaluated for trends including mean accuracy and the influence of the patient's gender on estimation. Correlation and regression analyses were used to find any association between estimated weight and actual weight. SAS was used to perform all analyses. (Version 8.02, SAS Institute, Inc., Cary, NC)

## RESULTS

Over the course of the study, 452 patients were approached for participation. A total of 56 patients refused, leaving 396 enrolled patients. Of those enrolled, 174 (43.9%) were women and 222 (56.1%) were men. The average age and weight of the women was 40 years and 75.37 kilograms (SD ± 20.08) while for men, average age was 39 years and weight 83.54 kilograms (SD ± 18.64).

Overall accuracy was defined as estimation within 5 percent of the patient's actual weight. The patient, attending physicians, resident physicians, paramedics, and nurses estimated within this interval 77.5%, 33.6%, 34.1%, 21.5%, and 32.9% respectively.

When compared with the actual weight, deviation from actual weight is expressed in Table 1. Table 2 shows the absolute error whereas Table 3 illustrates correlation coefficient (r) for the patient, attending physician, resident physician, paramedic, and nurse estimation of the patients' weight.

Health care workers over or underestimated weight by greater than 20% not infrequently (attending 14.7%, resident 13.4%, paramedic 17.4%, nurse 15.9%). Of the errors greater than 20% of the patient's actual weight, attendings, residents, and nurses generally underestimated the patient's weight (77%, 74%, 71%, respectively) while the paramedics more often overestimated weight (56%; Table 4). Patients equally over or underestimated their own weight; however, errors greater than 20% were rare.

The data were also analyzed with respect to patient's weight. When the patient's weight was 90 kg or greater, health care worker over or underestimation of weight by more than 20% was 25.3%, 25.0%, 19.4%, and 35.6% for attending physicians, resident physician, paramedic, and nurse respectively. Analysis by gender showed that in over and underestimations of 20% or more attendings, residents, and nurses consistently underestimated both genders but underestimated women more frequently than men ($P < .05$). In the same circumstances, EMS providers overestimated male weight while underestimating female weight less frequently than other providers ($P < .05$).

## DISCUSSION

In this study, the patient provided the most accurate estimation of weight followed in order of accuracy by the attending physician, resident physician, paramedic, and nurse. The knowledge of the patient's own estimate could save time and expense over the other methods for attaining weight.

**TABLE 2.** Absolute Error

| | Number of Patients (N) | Mean of Absolute Error (kg) With 95% Confidence Interval | Standard Deviation of Absolute Error | Statistical Significance (*P*) |
|---|---|---|---|---|
| Patient | 392 | 2.86 (2.54 3.19) | 3.26 | <.0001 |
| Attending | 292 | 8.87 (7.90 9.85) | 8.48 | <.0001 |
| Resident | 343 | 8.88 (7.96 9.81) | 8.73 | <.0001 |
| Paramedic | 144 | 9.77 (8.59 10.96) | 7.22 | <.0001 |
| Nurse | 383 | 9.20 (8.28 10.12) | 9.15 | <.0001 |

**TABLE 4.** Percent of Estimations Greater Than 20% of Patients' Body Weight

| | Total | Female | Male |
|---|---|---|---|
| Patient | 1.5 (0.6 3.3)* | 1.2 (0.1 4.1) | 1.8 (0.5 4.6) |
| | Over: 50.0% | Over: 0.0% | Over: 75.0% |
| | Under: 50.0% | Under: 100.0% | Under: 25.0% |
| Resident | 13.4 (10.0 17.5) | 16.9 (11.3 23.7) | 10.6 (6.6 15.9) |
| | Over: 26.1% | Over: 23.1% | Over: 30.0% |
| | Under: 73.9% | Under: 76.9% | Under: 70.0% |
| Attending | 14.7 (10.9 19.3) | 18.6 (12.3 26.4) | 11.7 (7.2 17.6) |
| | Over: 23.3% | Over: 25.0% | Over: 21.0% |
| | Under: 76.7% | Under: 75.0% | Under: 79.0% |
| Nurse | 15.1 (11.7 19.1) | 20.2 (14.4 27.1) | 11.2 (7.3 16.1) |
| | Over: 31.0% | Over: 23.5% | Over: 41.7% |
| | Under: 69.0% | Under: 76.5% | Under: 58.3% |
| EMS | 17.4 (11.6 24.6) | 18.2 (9.8 29.6) | 16.7 (9.2 26.8) |
| | Over: 56.0% | Over: 33.3% | Over: 76.9% |
| | Under: 44.0% | Under: 66.7% | Under: 23.1% |

*Binomial exact confidence interval.

Inaccurate pediatric weight estimation has been shown in several studies. In 1985 Garland et al studied weight estimation in 258 children using height, habitus, gender, and age with standardized weight curves to assist in their estimation.[9] Garland found that only 34% of estimates were within 10% of the actual weight using age alone, whereas 51% were within this margin using age and gender. Using all 4 criteria, they improved accuracy to only 61%. Dearlove reported a study of 50 children in which parental estimates were within 10% of the actual only 25% of the time.[10] Using an age-based table, weight estimations were within 10% only 36% of the time and using the Broselow tape brought the percentage up to 60%.

Uesugi reported the estimations of 48 pediatric patients by 5 physicians. The estimations correlated well with the actual weight with the exception of infants and children weighing less than 20 kg where the unacceptable error rate for some estimators was 69%.[11] Recently a comparison of six methods of weight estimation using mean percentage error concluded that the Broselow tape was the most accurate method.[8] Vilke studied paramedic estimation of pediatric patient weight.[12] Twenty paramedics estimated the weight of the same 4 children and estimated the epinephrine dose to be given to the 4.5-kg child based on their estimation. 12% of the estimates resulted in an incorrect epinephrine dose, and overall 10% were greater than 10 times the correct dose. Most paramedic estimations (91.5%) were within 50% of the actual weight (Vilke's measure of accuracy), although several paramedic estimation were more than 50% off. In Martin's study of paramedic weight estimations for 133 adult cardiac arrest patients, he found that the correlation for paramedic estimations compared with actual weights was 0.93. In our study, correlation coefficients for paramedic estimations were 0.79. Similar to the findings of our study, Martin's paramedics were within 20% of actual patient weights 90% of the time compared with 82% of our paramedics' estimations.[13]

Adult weight estimation by physicians has been studied on a more limited basis. A study by Coe et al examined weight estimation of supine patients before surgery but was limited by both the number of patients and providers involved.[14] Coe had 4 observers visually estimate the height and weight of 38 preoperative patients. He discovered marked variation in the ability of the observers to assess these characteristics accurately. The correlation coefficients of his 4 estimators ranged from 0.71 to 0.83 which corresponds well with our results. A study of weight estimation by 4 experienced ICU professionals assessing the weight of 30 supine, healthy volunteers in "dress blues" concluded that considerable and random error occurred.[15] The pooled correlation coefficient for all 4 estimators was 0.90 which is slightly better than that of our best estimation group.

Weight estimation by family members has also been studied.[16] Read and Price studied 374 first-degree relatives from 94 Caucasian families selected to be in an obesity gene study, where each participant estimated the weight and height of their relatives. This study concluded family estimates were within 3% to 5% of the measured weight.

Strunkard established that patients are able to give accurate estimations of their own weight.[17] Payette also found that patient estimations are highly correlated with their actual weight ($r > 0.90$).[18] These results are similar to those found in our study. Neither of these studies, though, made any comparison to the estimations of health care professionals.

## LIMITATIONS AND FUTURE QUESTIONS

The limitations of this study include determining the limits for unacceptable margin of error, a methodological confounder, and patient acuity. The margin of unacceptable dosage error has not been established in the literature and commentary has been linked to adverse outcomes not the underlying dosage error. Designing a study to detect dosing error is difficult as these errors often are not noticed or are related to the end adverse outcome, thus making a retrospective study unlikely to yield a better determination of unacceptable error.

In the methods of this study, the active, repeated weight estimation by staff members may have resulted in an increased focus on accurate estimation. Examining the subject of weight estimation may have improved staff accuracy. Since the patient was weighed before staff estimation, patient cueing the staff was still possible even considering instructions to the contrary.

Although the patients studied were medically stable, we assume this data would extrapolate to critically ill or unconscious patients. For this study an unconscious patient could not volunteer their own weight, and a critically ill patient may have altered mental status to affect their estimation as well.

## CONCLUSIONS

Our study showed that ED staff estimation of a patient's weight is often inaccurate. When available, the patient's own estimate can be used as their actual weight. When the patient is incapacitated, no proven method is widely available at this time to avoid this type of dosage error.

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