Conclusions—Clinicians are poor at approximating the weights of patients with stroke in the acute setting, especially when patients lie at the extremes of weight. Beds capable of weighing patients should be mandated in emergency rooms for patients with acute stroke.

Key Words: cerebral hemorrhage □ comorbidity □ regression analysis □ stroke □ tissue plasminogen activator
Statistical Analyses
Data were analyzed using SPSS v21 (IBM, New York, NY). A paired t test between estimated weight and measured weight determined difference between these variables. Thereafter, univariate analysis to identify variables associated with the weight estimation error variable was undertaken. Variables found to be significant were included in a multivariable regression analysis alongside variables determined to be biologically significant (age, sex, pre-r-tPA NIHSS, and comorbidities). The population was divided into tertiles based on measured weight and compared with one another for the weight estimation error using analysis of variance.

A deviation of ±10% dose from 0.9 mg/kg was used as a range for acceptable dosing of r-tPA.1–3 Frequencies were then obtained for patients receiving an acceptable dose of 0.81 to 0.99 mg/kg, overdose >0.99 mg or underdose <0.81 mg/kg. To investigate whether misdosing had an effect on functional outcome, we categorized the mRS at 7 days/on discharge into 2 separate dichotomous variables. mRS was divided into favorable outcome (0–1) and unfavorable outcome (2–6), as well as independent outcome (0–2) and dependent outcome (3–6).1,2 A binary logistic regression was then performed to ascertain any significant relationship between dosing and outcome.

Dose of alteplase (mg) was calculated for both estimated weight and measured weight for each tertile group and compared with a paired t test. Tertiles of measured weight were compared against one another for NIHSS improvement to determine any change in the magnitude of recovery between groups. Dose deviation from the optimum dose was calculated.

Results
Demographic details of the study population are presented in Table 1.
Clinicians underestimated mean difference weight by 1.13 kg (P<0.05) between estimated (71.41; SD, 14.20) and actual measured weight (72.54; SD, 16.17). Results were not altered after adjustment for covariables of age, sex, pre–r-tPA NIHSS, oral anticoagulants, and comorbidities using univariate and multivariate analysis.

To determine whether extremes of weight affected weight estimation, measured weight was divided into tertiles. Tertile 1 represents the lightest 81 patients weighing between 37 and 64.5 kg; tertile 2, 80 patients weighing 64.6 to 77.8 kg; and tertile 3, 81 patients weighing from 77.9 to 120 kg. Table 2 illustrates that the estimated weight error for individuals in the third (heaviest) tertile was significantly different from the lower tertiles (P<0.001). This association remained significant after removing patients with estimated weights >100 kg and after adjustment for covariables. Dose of alteplase (mg) was calculated for both estimated weight and measured weight for each tertile group and compared with a paired t test. Tertiles of measured weight were compared against one another for NIHSS improvement to determine any change in the magnitude of recovery between groups. Dose deviation from the optimum dose was calculated.

Effect of Estimation Error on Dose
Using the range 0.81 to 0.99 mg/kg as an acceptable dose, patients were divided into 3 groups: underdose, acceptable dose, and overdose. The majority of patients (80.3%) received a dose within the acceptable range. Consistent with underestimation of weight, more patients were in the underdosed category than the overdosed category, 11.5% and 8.1%, respectively.

Table 1. Descriptive Statistics for Patients With Stroke (n=242)

<table>
<thead>
<tr>
<th>Variables</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD)</td>
<td>71.2 (16.3)</td>
</tr>
<tr>
<td>Sex, male (%)</td>
<td>123 (50.8)</td>
</tr>
<tr>
<td>Thrombectomy (%)</td>
<td>7 (2.9)</td>
</tr>
<tr>
<td>Risk factors, yes (%)</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>143 (59.1)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>46 (19)</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>70 (28.9)</td>
</tr>
<tr>
<td>Current smoker</td>
<td>29 (12)</td>
</tr>
<tr>
<td>Previous smoker</td>
<td>43 (17.8)</td>
</tr>
<tr>
<td>Previous ischemic stroke</td>
<td>54 (22.3)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>35 (14.5)</td>
</tr>
<tr>
<td>Congestive cardiac failure</td>
<td>13 (5.4)</td>
</tr>
<tr>
<td>Medications, yes (%)</td>
<td></td>
</tr>
<tr>
<td>Aspirin/dipyridamol</td>
<td>58 (24)</td>
</tr>
<tr>
<td>Clopidogrel/other antiplatelet</td>
<td>28 (11.6)</td>
</tr>
<tr>
<td>Anticoagulants</td>
<td>10 (4.1)</td>
</tr>
<tr>
<td>Antihypertensive</td>
<td>48 (19.8)</td>
</tr>
<tr>
<td>Observations on admission, mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Systolic blood pressure*</td>
<td>153.1 (27.5)</td>
</tr>
<tr>
<td>Diastolic blood pressure*</td>
<td>80.9 (16.9)</td>
</tr>
<tr>
<td>Glucose†</td>
<td>7.4 (2.8)</td>
</tr>
<tr>
<td>NIHSS score, mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Pre-r-tPA‡</td>
<td>9.9 (6.8)</td>
</tr>
<tr>
<td>After 2 h§</td>
<td>7.4 (6.9)</td>
</tr>
<tr>
<td>At 24 h</td>
<td></td>
</tr>
<tr>
<td>At 72 h¶</td>
<td>5.4 (6.5)</td>
</tr>
<tr>
<td>At 7 days/discharge#</td>
<td>4.4 (6.6)</td>
</tr>
<tr>
<td>mRS score, frequency</td>
<td></td>
</tr>
<tr>
<td>Premorbid**</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>192</td>
</tr>
<tr>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>7 d/discharge††</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>66</td>
</tr>
<tr>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>34</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>ICH‡‡</td>
<td>17 (0.07)</td>
</tr>
</tbody>
</table>

ICH indicates intracerebral hemorrhage; mRS, modified Rankin Scale; NIHSS, National Institute of Health Stroke Scale; and r-tPA, tissue-type plasminogen activator.

* n=241.
† n=236.
‡ n=238.
§ n=235.
|| n=234.
¶ n=197.
# n=204.
** n=240.
†† n=216.
‡‡ n=234.
A paired t test was performed for each tertile of measured weight, comparing the estimated weight-based dose and the measured weight-based dose (Table 3). In the lowest and highest tertiles, this difference proved to be significant (P < 0.05). Patients in tertile 3 received an average dose of 77.6 mg where they should have received 80.0 mg, a deficit of 3.0%. By contrast, tertile 1 received 51.54 mg where they should have received 50.33 mg, resulting in an overdose of 2.42%. Using a dose error margin of ±10%, 7.1% of patients received an inaccurate dose (P = 0.01).

### Effect of Estimation Error on Clinical Outcome

We divided mRS at 7 days on discharge into favorable/unfavorable outcome and independent/dependent outcome; 58.1% of patients achieved a favorable outcome defined as mRS between 0 and 1. With an independent outcome, mRS between 0 and 2, this value increases to 70.0%.

Dosing groups defined as underdosed, acceptable dose, and overdosed were then analyzed to determine their effect on the mRS outcomes: favorable/unfavorable and independent/dependent. Dosing errors proved to have no effect on mRS measured outcome. Dosing groups were also compared with intracerebral hemorrhage rates but also had no effect (P = 0.66).

The NIHSS score improved from 9.9 to 4.4 between admission and 7 days on discharge on average (Table 1). Improvement in NIHSS was calculated to analyze the magnitude of recovery seen in different patient groups. Dose deviation from the optimum dose of 0.9 mg/kg was also calculated. A correlation was observed between measured weight and pre-tPA–adjusted NIHSS score, implying that heavier patients have more severe strokes (P < 0.001). Tertile 3 (heaviest) group had the largest mean deviation in dose of −0.04 mg/kg and the smallest improvement in NIHSS of 4.00. Patients in tertile 2 (average) were accurately dosed with a mean deviation of −0.02 mg/kg. This group saw the greatest improvement in NIHSS score. Conversely, those in tertile 1 had a comparatively smaller improvement in NIHSS score of 1.8 than those from tertile 3 (P = 0.048).

### Discussion

Our analysis suggests that clinicians tend to significantly underestimate a patients’ weight, and this is largely accounted for by the underestimation of patients in the heaviest tertile weighing between 77.9 and 120 kg although clinicians also tended to overestimate individuals who are in the lightest tertile.

As a consequence of estimation errors, incorrect dosing could negatively impact on patient outcome (increased intracerebral hemorrhage or ineffective thrombolysis). The majority of those in our study receiving an inaccurate dose were underdosed.

Those in tertile 2 were most appropriately dosed and saw the greatest improvement in NIHSS score. Conversely, those receiving the largest deviation in dose had a comparatively reduced improvement in NIHSS score by day 7/discharge. Heavier patients were also noted to have more severe baseline NIHSS scores and therefore have a greater potential benefit from appropriate thrombolysis, although may derive less benefit from r-tPA, but this does not explain the reduced improvement in NIHSS score for tertile 3, which represents one third of our population.

Other investigators have also demonstrated a large variation in the accuracy of weight estimations with clinicians possibly better at estimating weights closer to their own. The error rate for our study population was 19.7%, which falls between 2 previous studies of 38.2% and 14.9%. Estimating weight to determine r-tPA dose is certainly more widely practiced compared with anthropometric measurements, which can take as long as formally weighing patients.

Although our study is one of the largest conducted on weight estimation in the acute stroke setting to date and the

### Table 2. Comparison of Weight Estimation Error for Tertiles of Measured Weight Using Analysis of Variance (n=242)

<table>
<thead>
<tr>
<th>Measured Weight (kg)</th>
<th>Tertile 1, Mean Difference (P Value)</th>
<th>Tertile 2, Mean Difference (P Value)</th>
<th>Tertile 3, Mean Difference (P Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tukey’s honest significant difference and lowest significant difference analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 1 (37–64.5)</td>
<td>...</td>
<td>1.56 (0.307)</td>
<td>5.86 (&lt;0.001)</td>
</tr>
<tr>
<td>Tertile 2 (64.6–77.8)</td>
<td>−1.56 (0.307)</td>
<td>...</td>
<td>4.30 (&lt;0.001)</td>
</tr>
<tr>
<td>Tertile 3 (77.9–120)</td>
<td>−5.86 (&lt;0.001)</td>
<td>−4.30 (&lt;0.001)</td>
<td>...</td>
</tr>
</tbody>
</table>

| Least significant difference | Tertile 1 (37–64.5) | ... | 1.56 (0.143) | 5.86 (<0.001) |                      |
| Tertile 2 (64.6–77.8) | −1.56 (0.143) | ... | 4.30 (<0.001) | ... |                      |
| Tertile 3 (77.9–120) | −5.86 (<0.001) | −4.30 (<0.001) | ... |                      |

### Table 3. Paired t Test Between Theoretical Dose Based on Measured Weight Compared With Dose Based on Estimated Weight for Tertiles of Measured Weight (n=242)

<table>
<thead>
<tr>
<th>Measured Weight (kg)</th>
<th>Dose Based on Estimate (mg)</th>
<th>Dose Based on Measured (mg)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tertile 1 (37–64.5)</td>
<td>51.54</td>
<td>50.33</td>
<td>0.041</td>
</tr>
<tr>
<td>Tertile 2 (64.6–77.8)</td>
<td>63.64</td>
<td>63.83</td>
<td>0.745</td>
</tr>
<tr>
<td>Tertile 3 (77.9–120)</td>
<td>77.62</td>
<td>80.03</td>
<td>0.001</td>
</tr>
</tbody>
</table>
only study to include NIHSS outcomes in addition to mRS.\textsuperscript{1–3} Many limitations need to be considered. This was a retrospective study and subject to that bias. However, the data analyzed were from an extensive database of all consecutive patients with acute stroke admitted no matter what time of day. We, therefore, think that all patients have been captured. Although weight was measured within 24 hours, it may differ slightly from admission weight because of the effects of dehydration. Although weight estimation is necessary to determine tPA dose for the majority of patients, individuals weighing >100 kg receive the maximum dose, and therefore, weight estimation has no bearing on these individuals (and our results were preserved when these 17 patients were excluded). The study was conducted in a single city, London, United Kingdom. However, this capital city houses some of the largest acute stroke units in the country admitting nearly 2000 patients with stroke per year. Thus, we think that our data and results are likely to be representative of most stroke units. Finally, we would argue that those with the heaviest weight have the worst outcomes because of dosing errors, but it is possible that their outcomes were worse because of associated comorbidity although this was not the case in another large study addressing this issue.\textsuperscript{6} Notwithstanding this evidence, being overweight could be associated with bad outcome and underdosing may be a contributing factor to that outcome.

We conclude clinicians are poor at approximating the weights of patients with stroke in the acute setting, especially at the extremes of weight. These heaviest patients, approximately 1 in 3 of all thrombolysed patients, tend to be underdosed, which may lead to poorer outcomes. Our results argue in favor of beds capable of weighing patients in emergency rooms for patients with acute stroke who are unable to report their own weight.

Acknowledgments

P. Sharma is a former UK Department of Health Senior Fellow. He devised the idea and supervised the project. T. Barrow undertook the data collection, initial analysis, and wrote the first draft. M.S. Khan undertook the analysis. P. Bentley and O. Halse advised and supervised on the clinical aspects. All authors contributed to the final version of the article.

Disclosures

None

References

Estimating Weight of Patients With Acute Stroke When Dosing for Thrombolysis
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Supplemental Figure I:

Percentage estimation error of weight by tertiles of weight. Weight estimation error was greater at the extremes of weight (Tertile 1 & 3)