Blood Loss from Laboratory Tests

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Background: Laboratory tests can be an important source of blood loss in hospitals, especially for newborns and patients in intensive care. The aim of this study was to quantify blood loss for laboratory diagnostic tests in a large number of patients in a teaching hospital.

Methods: We estimated blood loss by multiplying the number and volumes of sampling tubes collected from 2654 adult inpatients. We compared the number of tests per patient for all inpatients and intensive care unit patients during the first period and again in the same time period 1 year later when cumulative blood-loss volumes were being reported to physicians and educational information had been given to decrease blood loss from laboratory tests.

Results: For 95% of the patients, blood loss during hospitalization was <196 mL. The largest proportion of the blood samples was used for clinical chemical tests (median, 45%), followed by hematologic (median, 26%) and coagulation (median, 17%) tests. In the surgical and cardiovascular surgical intensive care units, however, blood gas analyses accounted for 19–34% (medians) of the use. For 5% of the patients, all undergoing intensive care, blood loss was ≥200 mL and for 0.7% was ≥600 mL during their hospital stay. Such high blood losses were observed in patients with long-term ventilation, coagulation disorders, and repeated surgery. The largest median blood loss was in patients undergoing cardiovascular surgery (median, 201 mL). The mean number of tests was 44 per inpatient before cumulative blood loss was being reported and 46 when it was being reported.

Conclusions: Blood loss from laboratory diagnostic testing is not likely to pose a problem for most hospitalized patients. Blood loss is greater in intensive care patients and after cardiovascular surgical procedures. Reporting of the cumulative individual blood loss did not decrease blood loss for laboratory testing.

Materials and Methods

The study was performed in a 500-bed teaching hospital of the University of Tuebingen (Tuebingen, Germany).

We estimated blood loss associated with laboratory testing data for 2654 patients for whom the hospital stay was started within a 2-month period until the stay was finished. Most phlebotomies for patients outside intensive care...
care units (ICUs) were performed by medical students in their last year of clinical training, whereas most phlebotomies for patients in ICUs were performed by experienced nurses from arterial and venous lines. The investigated patient samples are categorized and summarized in Table 1. For each patient, the blood loss was estimated cumulatively by adding the volume of the tubes used for blood collection with the aid of a computer program (Medat). This software was used to calculate the cumulative diagnostic blood loss of each patient. Results were sent together with the laboratory results to the attending physicians. The volumes of the collection tubes (Sarstedt) are shown in Table 2. Routine chemistry tests (including hormones, tumor markers, therapeutic drugs, and serology) were from a menu of 105 tests and were performed with serum.

The frequency of secondary tubes was <1%. Analyzing instruments were as follows:

- For clinical chemistry tests: Ortho Vitros with a sample volume of 10 µL/test, a dead space of 30 µL, and primary-tube sampling,
- For coagulation tests: Dade Behring CA-1000 with a sample volume of 100 µL, a dead space of 500 µL, and primary-tube sampling,
- For immunoassays: Abbott AxSYM with a sample volume of 50 µL, a dead space of 100–150 µL, and primary-tube or aliquot-tube sampling,
- For blood gas analyses: ABL 625 with a sample volume of 85 µL, a negligible dead space with direct injection from the sample capillary, or a 1.9 mL dead space with syringe injection (rest of 2.4 mL sample tubes),
- For hematology: Sysmex K-1000 with a sample volume of 32 µL, a dead space of the rest of the 2.4 mL K-EDTA sample tube, and primary-tube sampling.

A complete blood count was defined as one test. Dead space is defined as the remaining sample volume after performance of one determination.

### Table 1. Investigated patient samples.

<table>
<thead>
<tr>
<th>Department</th>
<th>No. of patients</th>
<th>No. of ICU patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visceral surgery</td>
<td>473</td>
<td>42&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Gynecology</td>
<td>337</td>
<td></td>
</tr>
<tr>
<td>Obstetrics</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>Cardiovascular surgery</td>
<td>175</td>
<td>170</td>
</tr>
<tr>
<td>Gastroenterology</td>
<td>325</td>
<td>65&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nephrology</td>
<td>221</td>
<td></td>
</tr>
<tr>
<td>Oncology&lt;sup&gt;c&lt;/sup&gt;</td>
<td>416</td>
<td></td>
</tr>
<tr>
<td>Cardiology</td>
<td>527</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2654</td>
<td>277</td>
</tr>
</tbody>
</table>

<sup>a</sup> Total number of ICU patients in the visceral surgery, gynecology, and obstetrics departments.

<sup>b</sup> Total number of ICU patients in the gastroenterology, nephrology, oncology, and cardiology departments.

<sup>c</sup> Most of these patients had solid tumors because all chemotherapies in our hospital were performed in the department of oncology.

It should be noted that the estimation of blood loss by adding the volumes of the tubes used for blood collection does not account for the fact that not all containers were filled to nominal capacity. Consequently, the numbers indicated in the following tables are upper limits and have been rounded to take into account this lack of accuracy. However, because the participating hospital has established a fully centralized laboratory testing process and all intraoperative determinations and laboratory tests of intensive care patients were also performed by the central laboratory, the estimated data on blood loss are relatively complete except for the above-mentioned restrictions. No point-of-care testing was performed on the ward, on the ICU, or in the operating rooms except for ~4000 capillary blood glucose tests/month. This equates to 400 mL of whole blood and to a mean blood loss of 0.15 mL/patient. Therefore, the amount of blood loss attributable to point-of-care testing can be neglected, but only under the conditions of our hospital.

The laboratory is equipped and organized such that sample aliquoting is reduced to a minimum and the analyses are performed in the primary tube whenever possible. Sample transport from the ICUs and operating rooms is via a pneumatic tube sample transport system. For selected departments, the blood loss for patients was assessed both during treatment on the ward and during intensive care, including intraoperative analyses. The amount of testing was at the discretion of the ordering physicians except for patients enrolled in studies and ICU patients. No groups of tests were mandated. All tests were selectively ordered.

### Results

The blood loss data for all 2654 patients included in this study are listed in Table 3. The differences between median and mean clearly verify an asymmetrical distribution of measured values. The maximum values show deviations from the corresponding medians of up to 120-fold. For 5% of the patients tested, the total blood loss exceeded 196 mL. Our study group included patients receiving special treatments (daily blood loss in parenthe-
The major portion of total blood loss was attributable to clinical chemical analyses (36–51%), followed by hematologic (20–30%) and coagulation analyses (13–21%), without significant differences among the hospital departments.

Laboratory testing for intensive care treatment is considerably different from testing for treatment on a ward, as shown in Table 5. It should be noted that for cardiovascular surgery, a high percentage of the total blood loss (34%) is required for blood gas analyses in the ICU. The data for the 42 ICU patients in the visceral surgery and gynecology departments showed similar results except that ~19% were attributable to blood gas analyses.

Assuming that a total blood loss during an average hospital stay of <200 mL is usually not critical, we evaluated separately 131 patients from whom larger blood volumes had been collected (Fig. 1). As can be seen

As expected, the values for patients undergoing cardiovascular surgery were all markedly higher. The high number blood drawings among these patients (66) were attributable to repeated tests and were 9 times higher than the number of blood drawings for visceral surgery.

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Assuming that a total blood loss during an average hospital stay of <200 mL is usually not critical, we evaluated separately 131 patients from whom larger blood volumes had been collected (Fig. 1). As can be seen
clearly from the data, that the test covered two subgroups. A smaller group (n = 18; data points within the boxed area in Fig. 1) showed a linear increase in total blood loss during the intensive care treatment. For these patients, we found a linear correlation between length of stay and blood loss (Spearman correlation coefficient, 0.678). In the larger group, we found no clear correlation between blood loss and duration of the hospital stay.

Twenty-two patients of the entire group had a laboratory-related blood loss >600 mL during their hospital treatment. All of these patients were on long-term ventilation and had venous and/or arterial lines. These patients had a special blood-drawing protocol: at the beginning of an 8-h shift, a cell count, electrolyte and creatinine determinations, and depending on the clinical situation, acid-base assessment were ordered. Furthermore, when the ventilation scheme was changed, acid-base studies were again ordered.

We determined the number of tests per ICU patient within the first study period and in the same time period 1 year later after physicians had been informed about the individual cumulative blood loss. Before and after this intervention, physicians ordered, respectively, 44 and 46 tests per patient concerning all inpatients. For ICU patients, they ordered 93 and 85 tests per patient, respectively.

**Discussion**

For our study, we suggested that the loss of 200 mL of whole blood, the 95th percentile for our study patients, is not clinically critical for adults. Two hundred milliliters of whole blood is equivalent to the loss of 80 mL of erythrocytes (hematocrit, 40%). In the literature, no limit for “not clinically critical blood loss” can be found because such a “not critical volume” depends on many factors, e.g., initial hemoglobin concentration, underlying disease, age, and especially, on the variability in transfusion practice among institutions (11).

Only 5% of the 2654 patients included in the study had a laboratory-related blood loss >196 mL. The fact that the median is only two analyses per milliliter of serum demonstrates that the sample volume required for clinical chemical tests can be further reduced. Assuming that mostly primary blood collection tubes are used for analyses, that analyzer dead volume is 100 μL, and that the mean testing volume is 10–15 μL, the calculated sample volume for three determinations amounts to 130 and/or 250 μL of serum (12). According to the results of Dale and Pruett (5), 45 times (2- to 108-fold) more than the necessary amount of blood is taken. A comparison of our data with published results (4, 9, 10, 13) reveals a much lower diagnostic blood loss in the current study (18 mL/day vs 37–63 mL/day).

For 95% of all samples, the number of clinical-chemical determinations per milliliter of serum was five analyses or fewer. For each of these, 4.7 mL of blood was drawn. A major reduction in the diagnostic-related blood loss could be achieved by use of 2-mL sample containers for repetitive clinical-chemical tests and reducing the sample volume for blood gas analyses to 1 mL.

In 22 patients with long-term ventilation and venous and/or arterial catheters, laboratory-test-related blood loss was >600 mL. Among these patients, four were intensive care for 70–80 days. The other 18 patients show in a shorter time a linear increase in diagnostic blood loss in a critical clinical situation. The decisive factor for the blood loss was not the number of tests but the number of

<table>
<thead>
<tr>
<th>Department</th>
<th>Care unit</th>
<th>n</th>
<th>Hospitalization, days</th>
<th>Total blood loss, mL</th>
<th>Blood loss/day, mL</th>
<th>Distribution, %</th>
<th>No. of samplings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular surgery</td>
<td>ICU</td>
<td>170</td>
<td>4</td>
<td>144</td>
<td>40</td>
<td>21</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Ward</td>
<td></td>
<td>12</td>
<td>56</td>
<td>5</td>
<td>22</td>
<td>19</td>
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<tr>
<td>Visceral surgery/gynecology</td>
<td>ICU</td>
<td>42</td>
<td>3</td>
<td>63</td>
<td>26</td>
<td>25</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Ward</td>
<td>12</td>
<td>51</td>
<td>4</td>
<td>4</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>Internal medicine</td>
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<td>13</td>
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<td>19</td>
</tr>
<tr>
<td></td>
<td>Ward</td>
<td>11</td>
<td>37</td>
<td>4</td>
<td>4</td>
<td>18</td>
<td>16</td>
</tr>
</tbody>
</table>

*Fig. 1. Total blood loss for 131 patients with a blood loss >200 mL during hospitalization.*

There are two subgroups: one subgroup (n = 18) with a linear increase of blood loss with days per hospital stay (within the box), and one subgroup that shows no dependence on the time factor. Of these patients, 22 had a cumulative blood volume drawn per hospital stay of >600 mL. These were patients with venous and/or arterial lines and long-term ventilation.

<table>
<thead>
<tr>
<th>No. of samplings</th>
<th>Hematology</th>
<th>Hemostasis</th>
<th>Clinical chemistry</th>
<th>Acid-base status</th>
<th>Other</th>
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<tr>
<td>51</td>
<td>21</td>
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<td>34</td>
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<td>15</td>
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<tr>
<td>20</td>
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<td>14</td>
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<td>19</td>
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<tr>
<td>14</td>
<td>25</td>
<td>13</td>
<td>44</td>
<td>0</td>
<td>18</td>
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<tr>
<td>8</td>
<td>19</td>
<td>19</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>18</td>
<td>16</td>
<td>51</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
sample drawings caused by a rigid blood drawing scheme so that repetitive sample drawings were performed routinely irrespective of the patient’s clinical condition. On the basis of the total number of patients treated in the year of the study in the hospital, 142 patients with this high blood loss would be expected. This special patient group requires further measures to reduce the collection volumes.

In addition to the group of intensive care patients listed here, there are also other risk groups: e.g., low-birthweight newborns or patients with already existing anemia. According to Hicks (7), the increase in elderly patients could be another reason to reduce laboratory-related blood loss. Finally, the reduction of excess amounts of blood used for laboratory testing lowers the infection risk associated with administration of blood products.

A reduction in required blood volumes is in particular necessary for the above-mentioned risk groups. As shown in the investigation by Foulke and Harlow (14), the use of special collection containers in pediatric units led to a 50% reduction in the mean daily blood loss, but according to the results of Smoller et al. (15), the use of smaller collection containers did not affect the requesting behavior for laboratory tests that are not medically indicated. This statement compares to our experiences. The introduction of special catheters that reduce the blood loss up to 30% (9) was not realized because of the higher costs of these catheters.

Other methods for reduction of diagnostic blood loss include the use of plasma instead of serum, reduction of distribution into secondary tubes (12), and the use of whole-blood analyzers (6). A reduction in the number of repetitive tests and a change in requesting behavior would be the most effective method, but this is laborious to achieve because of the habits of the medical staff on the ward (7). In our study, reporting of the individual cumulative blood loss may have had an influence on the requesting behavior because the tests per ICU patient decreased. This reduction may be achieved not only by reporting the daily cumulative blood loss on the daily laboratory report but also by discussion in the wards.

In summary, in our study diagnostic blood loss did not pose a serious problem except for patients who underwent heart surgery and some patients who underwent visceral surgery. In all other departments, critical blood loss caused by laboratory testing was seen in only isolated cases under intensive care. To inform the attending physicians properly, our daily laboratory report always indicated the current cumulative blood loss of each individual patient. We close with the following recommendation “...but we shouldn’t draw more blood than we need. It can’t be good for the patient and it means biohazardous waste for the laboratory to dispose” (16).

References