Does Routine Repeat Testing of Critical Values Offer Any Advantage Over Single Testing?

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- **Context.**—Before being communicated to the caregiver, critical laboratory values are verified by repeat testing to ensure their accuracy and to avoid reporting false or erroneous results.

- **Objective.**—To determine whether 2 testing runs offered any advantage over a single testing run in ensuring accuracy or in avoiding the reporting of false or erroneous results.

- **Design.**—Within the hematology laboratory, 5 tests were selected: hemoglobin level, white blood cell count, platelet count, prothrombin time, and activated partial thromboplastin time. A minimum of 500 consecutive critical laboratory test values were collected retrospectively for each test category. The absolute value and the percentage of change between the 2 testing runs for each critical value were calculated and averaged for each test category and then compared with our laboratory’s preset, acceptable tolerance limits for reruns.

The concept of a critical value as a laboratory result that reflects a potentially life-threatening emergency was coined by Lundberg in the early 1970s. Since then, this concept has been adapted by national and state laboratory accreditation and regulatory agencies, such as the College of American Pathologists and the Joint Commission, and included in regulatory acts, such as the Clinical Laboratory Improvement Amendments of 1988. All these agencies require laboratories to have a list of critical test values and a documented system in place for timely reporting of such results to a licensed caregiver. It is left up to individual institutions to develop such a list and to formulate notification procedures.

Although there are no regulatory requirements for verification of critical value results by repeat analysis, laboratories do so to ensure accuracy and to avoid false-positive analytic errors. Because such a policy may cause some delay in reporting critical test results, in addition to increasing the analytic process cost, the need to routinely verify each critical value result by repeat analysis has been questioned in recent years. Based on an evaluation of repeat analyses for 580 critical laboratory values in chemistry, hematology, and coagulation testing, Chima et al recently reported that repeating critical values did not yield better accuracy and consequently considered it unnecessary for that purpose. We present here the data of a similar, but independently conducted, study on a much larger sample (2627 versus 580 critical laboratory values) representing a minimum of 500 critical values for each of the 5 selected tests: hemoglobin level (HGB), white blood cell count (WBC), platelet count (PLT), prothrombin time (PT), and activated partial thromboplastin time (APTT).

The aim of our study was to determine whether repeat testing of critical laboratory values offered any advantage over single testing in ensuring or improving result accuracy or in avoiding the reporting of false or erroneous results for common hematology and coagulation tests.

**MATERIALS AND METHODS**

Within the hematology laboratory, 5 tests were selected for analysis: HGB, WBC, PLT, PT, and APTT. The results for these tests were obtained by running the ethylenediaminetetraacetic acid–anticoagulated blood specimens for complete blood cell counts on theXE-2100 hematology analyzer (Sysmex Corporation of America, Mundelein, Illinois) and the citrated blood specimens for PT and APTT on an electromechanical clot detection-based analyzer (STAR-evolution or STAR coagulation analyzer, Diagnostica Stago, Inc, Parsippany, New Jersey). The repeat complete blood cell count test runs were performed either

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**Results.**—The mean results obtained for the absolute value and the percentage of change between the testing runs were 0.08 g/dL (1.4%) for hemoglobin levels, 50 cells/μL (10.2%) for white blood cell counts, 1500 cells/μL (9.9%) for platelet counts, 0.7 seconds (1.4%) for prothrombin time, and 5.1 seconds (4.4%) for activated partial thromboplastin time (all within our laboratory’s acceptable tolerance limits for reruns). The percentage of specimens with an absolute value or a mean percentage of change outside our laboratory’s acceptable tolerance limits for reruns ranged between 0% and 2.2% among the test categories. No false or erroneous results were identified between the 2 testing runs in any category.

**Conclusions.**—Routine, repeat testing of critical hemoglobin level, platelet count, white blood cell count, prothrombin time, and activated partial thromboplastin time results did not offer any advantage over a single run.

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on the same analyzer as on the initial run or on another XE-2100 in our laboratory. Similarly, the repeat PT and APTT runs were performed either on the same analyzer as on the initial run or on another analyzer (STAR-evolution or STAR) in our laboratory. All analyzers were calibrated periodically and maintained daily for quality control according to manufacturers’ instructions. A minimum of 500 consecutive critical laboratory values were collected retrospectively for each test category using institutionally established critical value limits. Although arbitrarily chosen, the number of collected critical values was set high in an effort to have a reasonable chance of identifying outliers and false or erroneous results. Criteria for excluding data from evaluation were limited to (1) results of specimens subjected to special handling, such as plasma replacement for lipemia or hyperbilirubinemia, between the 2 runs; and (2) any values reported as 0.0 (eg, <50 cells/μL). The cutoff range for critical laboratory values were as follows: HGB, ≤6.0 g/dL; PLT, ≤30,000 cells/μL; WBC, ≤15,000 cells/μL; PT, >35 seconds; and APTT, >90 seconds. The extremely low frequency of critical laboratory values at the high end for HGB, WBC, and PLT and at low end for PT and APTT reference ranges precluded their inclusion in the study. The critical laboratory values were obtained from patients with a wide age range and with a variety of clinical conditions, including neoplasia, infections, and autoimmune disorders. The absolute value and the percentage of change between the 2 test runs for each critical value were calculated and averaged for each test category and then compared with our laboratory’s (Department of Pathology, Anatomy, and Cell Biology, Thomas Jefferson University Hospital, Philadelphia, Pennsylvania) preset, acceptable tolerance limits for reruns (ATLRs) shown in Table 1. An absolute difference between 2 test runs that fell outside our laboratory’s preset ATLRs was considered an outlier. We considered a result erroneous when the values obtained by the 2 test runs of a specimen differed from each other by 2-fold or greater in absolute terms or by 100% or more in relative terms. In an attempt to determine whether the mean percentage of change varied with the range, the data for each test category were arbitrarily subdivided into 3 groups representing low, lower, and lowest range of values for HGB, WBC, and PLT and high, higher, and highest ranges for PT and APTT (Table 2). The specimens with absolute differences between the 2 test runs of greater than our laboratory’s preset ATLRs were tallied to determine the percentage of outliers and erroneous results for each test category.

**RESULTS**

The absolute difference between the 2 testing runs for individual specimens for each of the 5 tests are plotted against the respective mean test values obtained by averaging the 2 test runs in Figures 1 through 5.

**Hemoglobin**

The absolute differences in HGB critical values between the 2 testing runs for 498 individual specimens are plotted in Figure 1 against the mean HGB values within the range of 1.7 to 6.2 g/dL. The data of 2 specimens that were lipemic or icteric were excluded because the repeat test run was performed after plasma replacement. The repeat test runs for 221 specimens (44.4%) generated results identical to the initial test run; 197 specimens (39.6%) revealed a difference of 0.1 g/dL, 65 specimens (13.1%) revealed a difference of 0.2 g/dL, 14 specimens (2.8%) revealed a difference of 0.3 g/dL, and 1 specimen (0.2%) revealed a difference of 0.4 g/dL. In summary, 97% of the specimens on the repeated test run revealed a maximum difference of 0.2 g/dL.

**White Blood Cell Count**

The absolute differences between the 2 test runs of 493 individual specimen WBC critical values are plotted in Figure 2 against the mean WBC values within the range of 100 to 1600 cells/μL. The data from 7 specimens with WBC results of 0.0 (ie, <50 cells/μL) were excluded. The repeat test runs of 312 specimens (63.3%) generated results identical to the initial test run; 166 specimens (33.7%) revealed a difference of 100 cells/μL, 11 specimens (2.2%) revealed a difference of 200 cells/μL, and 4 specimens (0.8%) revealed a difference of 300 cells/μL. In summary, 97% of the specimens on the repeated test run revealed a maximum difference of 100 cells/μL.

**Platelet Count**

The absolute differences between the 2 test runs of 551 individual specimens in PLT critical values are plotted in Figure 3 against the mean PLT results within the range of 1000 to 30,000 cells/μL. The repeat test runs of 148 specimens (26.9%) generated results identical to the initial test run; 354 specimens (64.2%) revealed a difference of 100 to 3000 cells/μL, 32 specimens (5.8%) revealed a difference of 4000 to 5000 cells/μL, 15 specimens (2.7%) revealed a difference of 6000 to 10,000 cells/μL, and 2 specimens (0.4%) revealed a difference of 11,000 to 12,000 cells/μL.

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**Platelet Count**

The absolute differences between the 2 test runs of 551 individual specimens in PLT critical values are plotted in Figure 3 against the mean PLT results within the range of 1000 to 30,000 cells/μL. The repeat test runs of 148 specimens (26.9%) generated results identical to the initial test run; 354 specimens (64.2%) revealed a difference of 100 to 3000 cells/μL, 32 specimens (5.8%) revealed a difference of 4000 to 5000 cells/μL, 15 specimens (2.7%) revealed a difference of 6000 to 10,000 cells/μL, and 2 specimens (0.4%) revealed a difference of 11,000 to 12,000 cells/μL.
cells/μL. In summary, 91.1% of the specimens on the repeated test run revealed a maximum difference of 3000 cells/μL.

**Prothrombin Time**

The absolute differences between the 2 test runs of 533 individual specimens in PT critical values are plotted in Figure 4 against the mean PT results within the range of 37.4 to 74.8 seconds. The repeat runs of 25 specimens (4.7%) generated results identical to the initial test run; 486 specimens (91.2%) revealed a difference of 0.1 to 2 seconds, 19 specimens (3.6%) revealed a difference of 2.1 to 4 seconds, 1 specimen (0.2%) revealed a difference of 4.1 to 6 seconds, and 2 specimens (0.4%) revealed a difference of more than 6 seconds (8.3 seconds and 9.1 seconds). In summary, 99.4% of the specimens on the repeated test run revealed a maximum difference of 3 seconds.

**Activated Partial Thromboplastin Time**

The absolute differences between the 2 test runs of 552 individual specimens in APTT critical values are plotted in Figure 5 against the mean APTT results within the range of 91 to 168 seconds. The repeated test runs of 9 specimens (1.6%) generated results identical to the initial test run; 481 specimens (87.1%) revealed a difference of 1 to 10 seconds, 44 specimens (8.0%) revealed a difference of 11 to 20 seconds, 9 specimens (1.6%) revealed a difference of 21 to 30 seconds, 6 specimens (1.1%) revealed a difference of 31 to 40 seconds, and 3 specimens (0.5%) revealed a difference of more than 40 seconds. In summary, 96.7% of the specimens on the repeated test run revealed a maximum difference of 20 seconds.

The mean absolute difference, represented as a percentage of the mean test value (hereafter referred to as the mean percentage of change) for each test category and for subgroups of the WBC and PLT categories are depicted in Table 3. The lowest mean percentage of change was 1.4%, obtained for the HGB and PT results, and the highest mean percentage of change was 10.2%, obtained for the WBC results. Among the WBC subgroups, the low WBC result range of 100 to 500 cells/μL yielded a mean percentage of change of 15.2%, and the high WBC result range of 1100 to 1500 cells/μL yielded a mean percentage of change of 5.1%. Similarly, among the PLT subgroups, the low PLT result range of 1000 to 10 000 cells/μL yielded a mean percentage of change of 16.6%, and the high PLT result range of 21 000 to 30 000 cells/μL yielded a mean percentage of change of 6.7%. The mean percentage of change for the APTT results was 4.4. The attempts to subcategorize HGB, PT, and APTT data did not reveal any trends.
Outliers and Erroneous Results

The specifics of outliers are tabulated in Table 4. There was only 1 outlier (0.2%) in the HGB test category, none in the WBC test category, 12 (2.2%) in the PLT test category, 2 (0.4%) in the PT test category, and 11 (2.0%) in the APTT test category. The absolute differences associated with individual outliers were (1) 0.4 g/dL for the sole HGB outlier, with a mean value of 5.8 g/dL; (2) 7000 to 12,000 cells/μL for the 12 PLT outliers, with mean values in the range of 12,000 to 30,000 cells/μL; (3) 9.1 seconds and 8.3 seconds for the 2 PT outliers, with mean values of 52 seconds and 74.6 seconds, respectively; and (4) 28.9 to 64.1 seconds for the 11 APTT outliers, with mean values in the range of 118 to 144.6 seconds.

Abbreviations: APTT, activated partial thromboplastin time; HGB, hemoglobin level; PLT, platelet count; PT, prothrombin time; WBC, white blood cell count.

### Table 3. Critical Results: Mean Percentage of the Difference in Results Between Duplicate Test Runs

<table>
<thead>
<tr>
<th>Test</th>
<th>Subgroups</th>
<th>Result Range</th>
<th>Result Mean</th>
<th>No. of Specimens</th>
<th>Absolute Difference</th>
<th>Percentage of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>HGB, g/dL</td>
<td>All specimens</td>
<td>1.7–6.0</td>
<td>5.32</td>
<td>498</td>
<td>0.08</td>
<td>1.4</td>
</tr>
<tr>
<td>WBC, cells/μL</td>
<td>All specimens</td>
<td>100–1500</td>
<td>665</td>
<td>493</td>
<td>50</td>
<td>10.2</td>
</tr>
<tr>
<td>PLT, cells/μL</td>
<td>Subgroup A</td>
<td>100–500</td>
<td>239</td>
<td>230</td>
<td>12</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Subgroup B</td>
<td>600–1000</td>
<td>808</td>
<td>145</td>
<td>30</td>
<td>15.2</td>
</tr>
<tr>
<td></td>
<td>Subgroup C</td>
<td>1100–1500</td>
<td>1310</td>
<td>118</td>
<td>70</td>
<td>5.1</td>
</tr>
<tr>
<td>PT, s</td>
<td>All specimens</td>
<td>37–74</td>
<td>44.3</td>
<td>533</td>
<td>0.7</td>
<td>1.4</td>
</tr>
<tr>
<td>APTT, s</td>
<td>All specimens</td>
<td>91–165</td>
<td>110.2</td>
<td>552</td>
<td>5.1</td>
<td>4.4</td>
</tr>
</tbody>
</table>

### Table 4. Critical Results: Specifics of Outliers

<table>
<thead>
<tr>
<th>Test</th>
<th>Result Range</th>
<th>Total Specimens, No.</th>
<th>Outliers, No. (%)</th>
<th>Preset ATLRs*</th>
<th>Run 1</th>
<th>Run 2</th>
<th>Mean</th>
<th>Absolute Difference</th>
<th>Percentage of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>HGB, g/dL</td>
<td>1.7–6.0</td>
<td>498</td>
<td>1 (0.2)</td>
<td>0.3</td>
<td>6.0</td>
<td>5.6</td>
<td>5.8</td>
<td>0.4</td>
<td>6.9</td>
</tr>
<tr>
<td>WBC, cells/μL</td>
<td>100–1500</td>
<td>493</td>
<td>0 (0.0)</td>
<td>200–300</td>
<td>16</td>
<td>9</td>
<td>12.5</td>
<td>7</td>
<td>56.0</td>
</tr>
<tr>
<td>PLT, cells/μL</td>
<td>1000–30000</td>
<td>551</td>
<td>12 (2.2)</td>
<td>3000–5000</td>
<td>11</td>
<td>18</td>
<td>14.5</td>
<td>7</td>
<td>48.3</td>
</tr>
<tr>
<td>PT, s</td>
<td>37–74</td>
<td>533</td>
<td>2 (0.4)</td>
<td>10%</td>
<td>47.4</td>
<td>56.5</td>
<td>52</td>
<td>9.1</td>
<td>17.5</td>
</tr>
<tr>
<td>APTT, s</td>
<td>91–165</td>
<td>552</td>
<td>11 (2.0)</td>
<td>15%</td>
<td>101.5</td>
<td>136.1</td>
<td>118.8</td>
<td>34.6</td>
<td>29.1</td>
</tr>
</tbody>
</table>

Abbreviations: APTT, activated partial thromboplastin time; ATLRs, accepted tolerance limits on reruns; HGB, hemoglobin level; PLT, platelet count; PT, prothrombin time; WBC, white blood cell count.

* Our laboratory’s (Department of Pathology, Anatomy, and Cell Biology, Thomas Jefferson University Hospital, Philadelphia, Pennsylvania) preset ATLRs.

COMMENT

Specimen tests with critical results are generally rerun before reporting for 2 reasons: (1) to confirm that the result is accurate, and (2) to avoid reporting false or erroneous results. To determine whether repeating the analysis of specimen tests with critical results offered any benefit in ensuring or improving the accuracy of the results or in avoiding the reporting of false or erroneous results, we reviewed the absolute value and percentage of change between duplicate runs of 2627 specimens (498 HGB critical results, 493 WBC critical results, 551 PLT critical results, 533 PT critical results, and 552 APTT critical results). Repeat testing yielded results that were within our laboratory’s preset ATLRs on 2601 of 2627 specimens.
Specimens with repeat results outside our laboratory’s preset ATLRs included 1 HGB, 12 PLT, 2 PT, 11 APTT, and no WBC test results. Only 4 of the total 2627 critical test values (0.15%) became noncritical on repeat testing, and as a matter of our laboratory policy, the initial critical test value was reported as long as the difference between the 2 test runs was within our laboratory’s preset ATLRs. Three of the 4 test values that became noncritical on the repeated test were PLT result, which ranged between 22 000 and 34 000 cells/µL on the repeated test run, and were verified by platelet estimates from a blood smear (routinely performed in our laboratory on all specimens with initial PLT results that are less than 100 000 cells/µL to avoid reporting falsely low counts associated with platelet clumping in ethylenediaminetetraacetic acid–anticoagulated specimens). The fourth test value that became noncritical on retest was an APTT result, which changed from 126.6 seconds to 88.8 seconds on repeated test run. The larger degree of variation among the duplicate runs of the APTT test results in 11 specimens might be attributed, at least in part, to the known, but unpredictable, instability of specimens from patients on heparin therapy. At times, results from these patients reveal poor reproducibility, most likely due to heparin inhibition by platelet factor 4, released by activated platelets in the specimen, or due to poor strength of the clot formed in the testing process. Also of note is that there were no erroneous results among the first test run values or among the repeated test runs in each test category.

Among the WBC and PLT subgroups, the mean percentage of change was found to be inversely proportional to the count range. This was an expected finding because differences in percentages are necessarily larger with small ranges because the denominators are smaller. Similar variations in the mean percentage of changes were, however, not seen within the subgroups of HGB, PT, and APTT. The latter finding may be attributed, at least in part, to including only high-end critical value results in the PT and APTT evaluations, as compared with comparing only the low-end critical values for WBC and PLT results. The little variation in the mean percentage of changes among the subgroups of HGB may relate to the comparatively low degree of imprecision inherent in automated HGB measurement.

On repeated test runs, 97% of the specimens with critical HGB and critical WBC results revealed a maximum absolute difference of only 0.2 g/dL and 100 cells/µL, respectively. Similarly, 91% of the specimens with critical PLT results revealed a maximum absolute difference of only 3000 cells/µL. The respective maximum absolute differences observed for the PT and APTT results were 4 seconds in 98.4% of specimens and 20 seconds in 96.7% of specimens, respectively. The mean results obtained for the absolute value and the percentages of difference for all 5 test categories were well within our laboratory’s preset ATLRs, and we would not expect differences of the observed magnitude to be clinically significant.

In conclusion, our observations are in agreement with those of Chima et al8 that routine repeated testing of critical values does not offer better accuracy and, hence, is unnecessary. Repeated testing may, however, be useful in certain circumstances, such as for questionable or infeasible results on first run and for δ failures. Elimination of routine, repeat testing of critical values can help improve efficiency in critical result reporting as well as in reducing the incremental (ie, variable or unfixed) test cost by approximately 50% without compromising accuracy. Patient care may also be improved by immediate communication of critical results to the caregiver, allowing for quick intervention by the clinician. The actual effect of eliminating routine, repeat tests of specimens with critical laboratory results on clinical intervention and outcome needs to be investigated in future studies.

References