Proficiency Testing of Hb A1c: A 4-Year Experience in Taiwan and the Asian Pacific Region

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BACKGROUND: The correlation between hemoglobin A1c (Hb A1c) and risk for complications in diabetic patients heightens the need to measure Hb A1c with accuracy. We evaluated the current performance for measuring Hb A1c in the Asian and Pacific region by examining data submitted by laboratories participating in the Taiwan proficiency-testing program.

METHODS: Five fresh-pooled blood samples were sent to participating laboratories twice each year. The results were evaluated against target values assigned by the National Glycohemoglobin Standardization Program network laboratories; a passing criterion of ±7% of the target value was used. Measurement uncertainty at Hb A1c concentrations of 7.0% and 8.0% were determined.

RESULTS: A total of 276 laboratories from 11 countries took part in the Hb A1c survey. At the Hb A1c concentrations tested method-specific interlaboratory imprecision (CVs) were 1.1%–13.9% in 2005, 1.3%–10.1% in 2006, 1.2%–8.2% in 2007, and 1.1%–6.1% in 2008. Differences between target values and median values from the commonly used methods ranged from −0.24% to 0.22% Hb A1c in 2008. In 2005 83% of laboratories passed the survey, and in 2008 93% passed. At 7.0% Hb A1c, measurement uncertainty was on average 0.49% Hb A1c.

CONCLUSIONS: The use of accuracy-based proficiency testing with stringent quality criteria has improved the performance of Hb A1c testing in the Asian and Pacific laboratories during the 4 years of assessment.

Hemoglobin A1c (Hb A1c)6 measurements obtained for a period of 2–3 months provide an important index for assessing glycemic control in patients with diabetes. Results from the Diabetes Control and Complications Trial (DCCT) in patients with type 1 diabetes (1) and the United Kingdom Prospective Diabetes Study in patients with type 2 diabetes (2, 3) indicate that Hb A1c is directly related to the risk of development and progression of diabetic complications. The National Glycohemoglobin Standardization Program (NGSP) was established in 1996 to standardize Hb A1c testing, so that clinical laboratory results would be traceable to the clinical studies and outcomes from DCCT and the United Kingdom Prospective Diabetes Study (4, 5). Guidelines for the management of diabetes rely closely on the measurement of Hb A1c (6–8). Maintenance of Hb A1c at <7.0% has been recommended for the effective treatment of diabetes (9). In addition, recent studies have suggested that Hb A1c can be used for the screening and diagnosis of diabetes (10–12). Thus, precise and accurate measurement of Hb A1c is critical and essential for proper diabetes care.

Proficiency testing (PT) that is accuracy based is important for improving and maintaining the quality of laboratory test results. Both imprecision and bias influence PT performance. Studies have suggested that maintaining a CV of less than one-third of the PT limit will guarantee passing PT events, given a bias less than one-fifth of the PT limit (13, 14).

The Taiwan Society of Laboratory Medicine (TSLM) began an Hb A1c proficiency testing survey program in 2004 and has used NGSP-assigned target values to assess accuracy since 2005. In this study, we aimed to evaluate the current performance of Hb A1c testing in Taiwan and the Asian Pacific region by examining data submitted by laboratories participating in the TSLM Hb A1c survey.

The Laboratory Management Committee of the Asian Pacific Federation for Clinical Biochemistry started the Hb A1c project and invited its members to participate in the TSLM Hb A1c survey free of charge in 2005. The Hb A1c PT consists of 5 samples per survey shipped twice a year to each laboratory. For those laboratories outside the Taiwan area, only 1 survey per

6 Nonstandard abbreviations: Hb A1c, hemoglobin A1c; DCCT, Diabetes Control and Complications Trial; NGSP, National Glycohemoglobin Standardization Program; PT, proficiency testing; TSLM, Taiwan Society of Laboratory Medicine; SRLs, secondary reference laboratories; CAP, College of American Pathologists; MU, measurement uncertainty.
year was performed owing to the limited budget of the Asian Pacific Federation for Clinical Biochemistry. The TSLM began a process of accuracy grading based on NGSP-assigned target values for each survey sample in 2005. The survey samples were prepared from pooled human fresh whole blood from healthy and diabetic individuals. The blood samples were negative for HIV antibodies, hepatitis B surface antigen, and hepatitis C antibody. Sample deterioration was minimized by shipment on cold packs within 5 days of collection.

Reported methods included: (a) Bio-Rad D-10, (b) Bio-Rad Variant II, (c) Fujirebio immunoturbidimetry, (d) Primus affinity chromatography, (e) Roche Cobas Integra immunoassay, (f) Tosoh G7 Standard analysis mode, (g) Tosoh G7 Variant analysis mode, and (h) Tosoh A1c 2.2 Plus. Methods (a), (b), and (f)–(h) are automated ion-exchange HPLC assays. All methods except method (c) are NGSP certified as traceable to the DCCT reference method.

Participants’ results were evaluated according to several different accuracy-based grading schemes, the criteria of TSLM (±7% of the NGSP target), the College of American Pathologists (CAP; 2008 criterion ±12% of the NGSP-target), and the Royal College of Pathologists of Australasia’s Quality Assurance Program (±0.5% Hb A1c if <10.0% Hb A1c, or ±5% of the DCCT-target if >10.0% Hb A1c). Acceptable performance was deemed as at least 80% of PT samples within the acceptable limits. We also analyzed the results obtained from 4 consecutive years, including method-specific median, mean, interlaboratory imprecision (CV), and bias for methods with participant numbers ≥10. The observed trueness (bias) for each method was assessed from the difference between the method-specific mean and the NGSP target value. Measurement uncertainty (MU) for each method was calculated from the square root of the sum of the squares of method-specific bias and method-specific SD, with a coverage factor of 2.

Table 1. Performance of 2 Hb A1c survey samples in commonly used methods of the TSLM proficiency-testing survey.

<table>
<thead>
<tr>
<th>Method</th>
<th>Labs</th>
<th>Mean</th>
<th>SD</th>
<th>CV%</th>
<th>Bias</th>
<th>Bias%</th>
<th>MU, % Hb A1c</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2007</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-10</td>
<td>43</td>
<td>7.29</td>
<td>0.21</td>
<td>2.93</td>
<td>0.26</td>
<td>3.7</td>
<td>0.67</td>
</tr>
<tr>
<td>Variant II</td>
<td>30</td>
<td>7.11</td>
<td>0.17</td>
<td>2.36</td>
<td>0.08</td>
<td>1.1</td>
<td>0.38</td>
</tr>
<tr>
<td>Fujirebio</td>
<td>11</td>
<td>6.97</td>
<td>0.36</td>
<td>5.17</td>
<td>−0.06</td>
<td>−0.9</td>
<td>0.73</td>
</tr>
<tr>
<td>Primus</td>
<td>22</td>
<td>7.18</td>
<td>0.14</td>
<td>1.95</td>
<td>0.15</td>
<td>2.1</td>
<td>0.41</td>
</tr>
<tr>
<td>Roche Integra</td>
<td>17</td>
<td>6.96</td>
<td>0.19</td>
<td>2.73</td>
<td>−0.07</td>
<td>−1.0</td>
<td>0.40</td>
</tr>
<tr>
<td>G7 Standard</td>
<td>30</td>
<td>7.15</td>
<td>0.14</td>
<td>1.97</td>
<td>0.12</td>
<td>1.7</td>
<td>0.37</td>
</tr>
<tr>
<td>G7 Variant</td>
<td>29</td>
<td>7.2</td>
<td>0.14</td>
<td>1.94</td>
<td>0.17</td>
<td>2.4</td>
<td>0.44</td>
</tr>
<tr>
<td>A1c 2.2 Plus</td>
<td>22</td>
<td>7.18</td>
<td>0.22</td>
<td>3.09</td>
<td>0.15</td>
<td>2.1</td>
<td>0.53</td>
</tr>
<tr>
<td><strong>Total/weighted mean</strong></td>
<td>204</td>
<td>7.16</td>
<td>0.18</td>
<td>2.58</td>
<td>0.13</td>
<td>1.87</td>
<td>0.49</td>
</tr>
<tr>
<td><strong>2008</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-10</td>
<td>41</td>
<td>7.84</td>
<td>0.24</td>
<td>3.06</td>
<td>−0.12</td>
<td>−1.5</td>
<td>0.54</td>
</tr>
<tr>
<td>Variant II</td>
<td>25</td>
<td>7.79</td>
<td>0.26</td>
<td>3.34</td>
<td>−0.17</td>
<td>−2.1</td>
<td>0.62</td>
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<tr>
<td>Primus</td>
<td>22</td>
<td>8.09</td>
<td>0.14</td>
<td>1.73</td>
<td>0.13</td>
<td>1.6</td>
<td>0.38</td>
</tr>
<tr>
<td>Roche Integra</td>
<td>20</td>
<td>7.95</td>
<td>0.48</td>
<td>6.04</td>
<td>−0.01</td>
<td>−0.1</td>
<td>0.96</td>
</tr>
<tr>
<td>G7 Standard</td>
<td>36</td>
<td>8.06</td>
<td>0.14</td>
<td>1.74</td>
<td>0.10</td>
<td>1.3</td>
<td>0.34</td>
</tr>
<tr>
<td>G7 Variant</td>
<td>29</td>
<td>8.15</td>
<td>0.17</td>
<td>2.09</td>
<td>0.19</td>
<td>2.4</td>
<td>0.51</td>
</tr>
<tr>
<td>A1c 2.2 Plus</td>
<td>13</td>
<td>8.11</td>
<td>0.13</td>
<td>1.60</td>
<td>0.15</td>
<td>1.9</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>Total/weighted mean</strong></td>
<td>186</td>
<td>7.98</td>
<td>0.22</td>
<td>2.75</td>
<td>0.02</td>
<td>0.31</td>
<td>0.52</td>
</tr>
</tbody>
</table>

* MU (expanded uncertainty), calculated from the square root of the sum of the squares of method-specific bias and method-specific SD, with a coverage factor of 2.
factor for the weighted mean was the number of laboratories in each method-specific group.

Laboratories participating in the Hb A1c Survey in Taiwan and the Asian Pacific region included hospital-based laboratories, freestanding facilities, and physician office laboratories. Each year there were 208–276 laboratories in Taiwan and 13–15 laboratories outside Taiwan enrolled in this program. The participants located outside Taiwan included Australia (n = 1), Hong Kong (n = 1), Indonesia (n = 2), India (n = 2), Korea (n = 1), Malaysia (n = 3), Pakistan (n = 2), Singapore (n = 4), Thailand (n = 1), and Vietnam (n = 1). All participants reported results as percentage Hb A1c.

Ion-exchange HPLC methods were used by 57% of laboratories in 2005; this percentage increased to 73% in 2008. Immunoassay methods were used in 26% of laboratories in 2005 and 16% in 2008. The remaining participants used affinity HPLC.

The method-specific interlaboratory imprecision values (CVs) ranged from 1.3% to 11.4% in 2005, 1.4% to 9.0% in 2006, 1.9% to 7.4% in 2007, and 1.6% to 6.1% in 2008 at Hb A1c concentrations of 6.0%–8.0%. In 2008, the CVs of HPLC-based methods were 1.1%–4.1% at Hb A1c concentrations of 4.8%–9.1%, whereas the interlaboratory CVs for immunoassays were 3.8%–6.1%. There were 4 methods (Primus and Tosoh G7 Standard, G7 Variant, and A1c 2.2 Plus) having inter-laboratory CVs less than one-third of the PT limit (2.3%) at Hb A1c concentrations ≥5.0%. This inter-laboratory CV is consistent with the CAP survey results, which showed CVs of 1.5%–3.5% for HPLC methods and 3.5%–8.0% for immunoassays (16).

Several expert groups in laboratory medicine recommended within-laboratory and between-laboratory imprecision goals of 3% and 5%, respectively (6, 17). Overall assessment revealed that the imprecision for all HPLC methods was good and fulfilled the quality goal. An optimal within-laboratory imprecision goal of 2% was advocated recently (18). The comparable between-laboratory CV is estimated as 3.3%. However, only about one-half of analytical methods used in this survey achieved this quality goal of imprecision at all concentrations tested in 2008, and all of the methods that achieved this goal were HPLC based.

Differences between NGSP-assigned target values and method-specific median values at the low, medium, and high Hb A1c concentrations from 7 NGSP-certified methods were within 0.4%, 0.2%, and 0.5% Hb A1c of NGSP targets, respectively, in 2006; within 0.2%, 0.3%, and 0.6% Hb A1c in 2007, and within 0.2%,
0.2%, and 0.3% Hb A₁c in 2008. The variability and bias trends at 7.0%–8.0% Hb A₁c during the 4 years are shown in Fig. 1 in the Data Supplement that accompanies the online version of this Brief Communication at http://www.clinchem.org/content/vol55/issue10. Three methods (Primus and Tosoh G7 Standard and Variant modes) had systematic error less than one-fifth of the PT limit (1.4%), calculated from the regression lines between NGSP-target values vs method-specific medians during the 4 years at the concentration of 7.0% Hb A₁c. The difference plots against NGSP-assigned target values are shown in online Supplemental Fig. 2. A larger median positive bias at high concentrations (8.0%–11.2%) of Hb A₁c was found during 2005–2007 in most methods. This positive bias in high-concentration survey samples was also reported in CAP surveys (16). The cause of the bias is unclear. However, the difference plots indicate that the bias has resolved over time.

The performance of Hb A₁c assessed from 2007 and 2008 data for samples with NGSP-assigned target values of 7.03% Hb A₁c and 7.96% Hb A₁c, respectively, is shown in Table 1. The range of the method-specific bias was −0.07% to 0.26% Hb A₁c and −0.17% to 0.19% Hb A₁c at the levels of 7.03% Hb A₁c and 7.96% Hb A₁c, respectively. Method-specific MU ranged from 0.37% to 0.73% Hb A₁c in 2007 and 0.38% to 0.96% Hb A₁c in 2008. National Academy of Clinical Biochemistry guidelines suggest interpreting changes of more than 0.5% Hb A₁c reporting units as ones for treatment (19). Our data on mean MU (0.49% Hb A₁c) conform to the 0.5% Hb A₁c change criterion. This change criterion of a 0.5% Hb A₁c reporting unit corresponds to results within ±7% of the target value in the PT scheme being adequate to meet clinical needs.

Acceptable performance for each method during the 4-year study period is shown in Fig. 1. The overall pass rates for the laboratories were 83%, 91%, 90%, and 93% in 2005, 2006, 2007, and 2008, respectively. Based on the CAP 2008 survey criterion, 90%–98% of laboratories performed adequately during the 4 years. Based on the Australian survey criterion, the overall pass rates were improved from 79% in 2005 to 93% in 2008 (online Supplemental Fig. 3).

Studies have shown that decreases in Hb A₁c reduced the risk of complications in diabetes (3, 7). Stringent analytical quality goals for Hb A₁c would provide improved precision and accuracy, facilitating better assessment of patient glycemic control. Use of pooled fresh human blood as PT survey samples was recommended to accurately assess the performance of Hb A₁c testing by avoiding potential sample matrix effects during shipping and processing. The NGSP SRL network is anchored by the DCCT reference method, which has proven to be consistent during a 25-year period (20). The network is also monitored against the IFCC definitive reference method, and the uncertainty (2 SD) of values assigned by the NGSP network has been shown to be 0.10% Hb A₁c (21). Thus, the contribution of the uncertainty of the NGSP value assignments to the total uncertainty of the Taiwan Proficiency Survey results is negligible. With the NGSP-assigned target values, the accuracy-based Hb A₁c survey enables laboratories to evaluate harmonization among methods and traceability to the DCCT reference method (6).

The improvement of interlaboratory CVs and bias and pass rate during the 4 years suggests that the PT program played a role in this improvement. The majority of the participants using NGSP-certified methods showed an acceptable Hb A₁c testing performance. Nevertheless, the deficiencies found in some laboratories confirm the need for continuing quality improvement for Hb A₁c measurement.

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