Understanding the new HbA₁c units for the diagnosis of Type 2 diabetes

Geoff D Braatvedt, Tim Cundy, Michael Crooke, Chris Florkowski, Jim I Mann, Helen Lunt, Rod Jackson, Brandon Orr-Walker, Timothy Kenealy, Paul L Drury

Abstract
In New Zealand laboratories the measurement of glycated haemoglobin (HbA₁c) for diagnosis of diabetes is now only reported in SI units of mmol/mol. HbA₁c is now recommended as the preferred test to diagnose diabetes in most circumstances. The requirement for a second positive test in asymptomatic individuals is retained. An HbA₁c ≥50 mmol/mol (repeated on a second occasion in asymptomatic patients) is diagnostic of diabetes and a value ≤40 mmol/mol represents normal glucose tolerance. For patients with an initial HbA₁c result of 41–49 mmol/mol, cardiovascular risk assessment and lifestyle interventions are recommended with repeat HbA1c screening in 6–12 months. For patients whose HbA1c is ≤40 mmol/mol, repeat screening (including for CVD risk) at intermittent intervals is recommended as per published guidelines.

In the absence of overt symptoms of hyperglycaemia, the diagnosis of diabetes has been based on plasma glucose concentrations that are associated with an increased risk of its specific microvascular complications, in particular retinopathy.¹,² The precise criteria have always been determined by consensus among experts and are based principally on several large observational cohort studies.

The criteria have been repeatedly modified over time as more high quality data have become available. Most recently many international diabetes societies have adopted the measurement of glycated haemoglobin (HbA₁c) as a legitimate diagnostic test for the diagnosis of diabetes using a “cut point” for the diagnosis of ≥6.5%.³⁻⁵

Recently there has been a change in the reporting units for HbA₁c from percent to mmol/mol that has been driven by the International Federation of Clinical Chemistry (IFCC) and is linked to the standardisation of routine assays for HbA₁c to a new reference method.⁶

The validity of the process has been accepted by many international diabetes societies (American Diabetes Association, Canadian Diabetes Society, European Association for the Study of Diabetes and International Diabetes Federation) as well as by the New Zealand Society for the Study of Diabetes (NZSSD).⁷

A NZSSD Working Party, made up of members representing clinicians, academics, laboratory staff, general practitioners and population health experts, has developed and now published a new position statement for the diagnosis of diabetes.⁷ This article explains the changes in use of HbA₁c recommended in that statement and expands on the evidence behind these modifications.
New units

All methods used to measure HbA₁c in New Zealand are now standardised through traceability to the IFCC reference method. From August 2009–September 2011, HbA₁c was reported in both the new SI units of mmol/mol and the derived percentage using a master equation (IFCC-NGSP). From October 2011, HbA₁c in New Zealand has been reported using mmol/mol only, although published research papers will continue to report dual units for the foreseeable future.

The change to new units has come about as laboratory methodology and measurement of ‘true’ HbA₁c has improved with resulting slightly lower absolute percentage values than previously reported, which could lead to confusion in setting new (slightly lower) targets for equivalent control versus older methods. Furthermore many patients mistakenly interpret an HbA₁c of, for example, 8% as equivalent to their average glucose level also being 8 mmol/L when, in fact, the estimated average glucose for an HbA₁c of 8% is about 11 mmol/L. In the new units an HbA₁c of 8% is equivalent to 64 mmol/mol.

Tables converting mmol/mol to the percentages obtained with the old methods are readily available (www.nzssd.org.nz), see Table 1.

Hopefully during this transition these tables will help both patients and healthcare professionals interpret the new units and better understand what the new targets for good control in patients with established diabetes might be, see Table 2.

Table 1. HbA₁c conversion table (www.nzssd.org.nz)

<table>
<thead>
<tr>
<th>HbA₁c mmol/mol</th>
<th>HbA₁c %</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>4.0</td>
</tr>
<tr>
<td>25</td>
<td>4.4</td>
</tr>
<tr>
<td>30</td>
<td>4.9</td>
</tr>
<tr>
<td>35</td>
<td>5.4</td>
</tr>
<tr>
<td>40</td>
<td>5.8</td>
</tr>
<tr>
<td>45</td>
<td>6.3</td>
</tr>
<tr>
<td>50</td>
<td>6.7</td>
</tr>
<tr>
<td>55</td>
<td>7.2</td>
</tr>
<tr>
<td>60</td>
<td>7.6</td>
</tr>
<tr>
<td>65</td>
<td>8.1</td>
</tr>
<tr>
<td>70</td>
<td>8.6</td>
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<tr>
<td>75</td>
<td>9.0</td>
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<td>9.5</td>
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<tr>
<td>100</td>
<td>11.3</td>
</tr>
<tr>
<td>110</td>
<td>12.2</td>
</tr>
<tr>
<td>120</td>
<td>13.1</td>
</tr>
</tbody>
</table>
Table 2. Reporting and interpreting glycated haemoglobin (HbA1c) results (www.nzssd.org.nz/HbA1c)

When performed in those with confirmed diabetes

<table>
<thead>
<tr>
<th>HbA1c value (mmol/mol)</th>
<th>Individual targets should be set using these suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 50</td>
<td>Excellent control; increased risk of hypoglycaemia if on insulin/sulphonylureas</td>
</tr>
<tr>
<td>50–54</td>
<td>Very good control; some risk of hypoglycaemia if on insulin/sulphonylureas</td>
</tr>
<tr>
<td>55–64</td>
<td>May be appropriate and acceptable in many individuals but higher than ideal from clinical trial evidence. Microvascular complication risk increases exponentially above around 55mmol/mol</td>
</tr>
<tr>
<td>65–79</td>
<td>Suboptimal glycaemic control. Consider more intensive treatment. Microvascular complication risk increases exponentially above around 55mmol/mol</td>
</tr>
<tr>
<td>80–99</td>
<td>Poor glycaemic control. More intensive treatment recommended. Microvascular complication risk increases exponentially above around 55mmol/mol</td>
</tr>
<tr>
<td>100 or more</td>
<td>Very poor glycaemic control. Warrants immediate action</td>
</tr>
</tbody>
</table>

HbA1c may be misleading in some situations (e.g. haemoglobinopathies, increased red cell turnover or after recent blood transfusion)

When performed for diagnosis/CV risk screening

<table>
<thead>
<tr>
<th>HbA1c value (mmol/mol)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 or less</td>
<td>Virtually excludes diabetes. No need to repeat HbA1c until next scheduled CVD risk assessment</td>
</tr>
<tr>
<td>41–49</td>
<td>Abnormal glucose tolerance Recommend diet/lifestyle changes and assess/manage all CV risk factors Repeat HbA1c annually unless asymptomatic in interim</td>
</tr>
<tr>
<td>50 or greater</td>
<td>Supports diagnosis of diabetes (in asymptomatic people must be confirmed on a second HbA1c sample after an interval) Recommend diet/lifestyle changes and assess/manage CV risk factors Start regular retinal, urinary microalbumin, renal function and foot screening</td>
</tr>
</tbody>
</table>

Glucose-based diagnostic criteria should always be used in situations where HbA1c is unreliable (e.g. haemoglobinopathies, increased red cell turnover or after recent blood transfusion).

New cut points for diabetes diagnosis

This discussion is focussed primarily on the diagnosis of Type 2 diabetes and does not address the question of the diagnosis of diabetes in pregnancy.

Glycaemia and retinopathy—The relationship between the presence of significant diabetic retinopathy and fasting plasma glucose(n=41,411), HbA1c (n=28,010) and the 2-hour glucose following an oral glucose tolerance test (OGTT –n=21,334) in patients undergoing screening for diabetes, has recently been reported and includes 9 studies from 5 countries.10 The relationship is curvilinear, with retinopathy risk very low for
fasting glucose <6 mmol/L and for HbA1c < 6% (<42 mmol/mol). A threshold for an increase in risk was observed for fasting glucose between 6.5–6.9 mmol/L and for HbA1c between 6.5–6.9% (48–52 mmol/mol). Compared with those with a fasting glucose of 4–4.4 mmol/L or an HbA1c of 4.0–4.4% (20–25 mmol/mol) the first interval at which risk was significantly higher was 6.5–6.9 mmol/L and the corresponding interval for HbA1c 6.5–6.9% (48–52 mmol/mol). Thus maintaining the current fasting plasma glucose cut-point for diabetes diagnosis of ≥7 mmol/L is reasonable.

Based on these findings, patients with fasting plasma glucose values of 6.1–6.9 mmol/L can be considered to have “impaired fasting glucose”, “dysglycaemia” or “pre-diabetes” and those with a fasting glucose of ≤6 mmol/L to have normal glucose values. Many of these patients may of course have other metabolic risk factors and carry a higher risk for cardiovascular events. Indeed patients with fasting glucose values between 5.5–5.9 mmol/L (“high fives”) are known to have a higher prevalence of markers of insulin resistance and are at higher risk of cardiovascular events than people with fasting glucose of ≤5.5 mmol/L. Patients undergoing screening for diabetes should thus also have a cardiovascular risk assessment using published guidelines.

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**Blood glucose criteria for diagnosing diabetes—no change; although no longer recommended as test of first choice**—The criteria for the diagnosis of diabetes in a patient with hyperglycaemic symptoms is currently based on a fasting plasma glucose of ≥7 mmol/L or 2-hour value after OGTT using a standard 75g load of glucose ≥11.1 mmol/L (or random plasma glucose of ≥11.1 mmol/L). In asymptomatic patients, a second result above these thresholds is also required. Patients are then classified as having normal glucose tolerance, impaired fasting glycaemia, impaired glucose tolerance or diabetes. While these glucose-based criteria remain unchanged, this paper discusses the rationale for using HbA1c as the preferred diagnostic test.

**Limitations of blood glucose in diagnosis of diabetes**—Overall biological reproducibility of oral glucose tolerance testing is poor, in the order of 66%, which can result in inappropriate labels being given to patients. Furthermore no attempt at weight adjusting the amount of glucose is included in adult OGTT protocols—a 60 kg person given 75g glucose receives twice the dose in mg/kg compared to a 120 kg person. This in part explains the poor correlation of 2-hour post OGTT glucose concentrations with significant prevalent diabetic retinopathy in patients with previously undiagnosed diabetes compared with glucose and HbA1c, and it is therefore somewhat arbitrary that the 2-hour post OGTT cut point for diabetes is currently set at ≥11.1 mmol/L.

The OGTT is also an expensive, inconvenient and unpleasant test and very time-consuming for the patient and laboratory. For all these reasons, the NZSSD Working Party, in line with many other countries, has recommended that the use of OGTT in the diagnosis of diabetes be largely abandoned.

For an individual, the biological variability of fasting plasma glucose is in the order of 4.5% and in addition, within-laboratory laboratory CV is in the order of 2.5% (RCPA Quality Assurance Programme). Ideally when measuring plasma glucose, the venous blood sample should be spun and plasma separated within minutes of
taking the sample as red blood cells continue to consume glucose at about 7% per hour in vitro, leading to a falsely low measured glucose.

Collection of the sample into a container with a glycolytic preservative (fluoride) has no effect on this process until about 1 hour after collection and only prevents further glycolysis after about 4 hours. Ideally the sample should also be placed in iced water and assayed within 30–60 minutes. Most laboratories, however, do not fulfil these rigorous sample handling requirements although nor have the many epidemiological studies upon which diagnostic criteria are based!

Apart from the day to day biological and laboratory method variability outlined above, patients requiring fasting plasma glucose additionally have the inconvenience of attending a laboratory in the fasting state which can be difficult for patients and laboratories alike.

**HbA₁c for the diagnosis of diabetes**

Whilst a fasting venous laboratory measured glucose of ≥7 mmol/L remains an acceptable cut point for the diagnosis of diabetes (when repeated on a separate occasion in an asymptomatic patient), the NZSSD now recommends using the HbA₁c as the preferred diagnostic test for most patients.

Throughout the 90–120 day lifespan of the red blood cell, haemoglobin is glycated in proportion to the mean exposure to glucose. Thus, the measured HbA₁c represents an integrated measurement of about 3 months’ worth of glucose exposure and is thus a more robust measure of glycaemia than single or repeated measurements of fasting plasma glucose.

As a result, the day-to-day biological variability of HbA₁c is small; in the order of 3.4%. The HbA₁c is not affected by prandial status and has no circadian rhythm, allowing measurement at any time of day. Moreover, unlike plasma glucose, the HbA₁c test shows minimal pre analytical error—i.e. is very stable after collection with no change in its concentration ‘in the collection tube’. Furthermore, the intra- and between laboratory analytic variability is small in the order of 2.5%.

Since 2009 the American Diabetes Association has accepted an HbA₁c of ≥6.5% (48 mmol/mol) as a diagnostic criteria for the diagnosis of diabetes. The units for the measurement of glucose in the USA are not SI and the USA will continue to use percentage units to report HbA₁c. The American Diabetes Association has stipulated analytical standards for HbA₁c measurement of intra-laboratory CV < 2% and between laboratory CV<3.5%, which are largely met within New Zealand.

As previously described, the threshold for detecting an increase in the prevalence of significant diabetic retinopathy in people without a known diagnosis of diabetes is an HbA₁c of approximately 6.5–6.9% (48–52 mmol/mol). Similarly the risk of significant prevalent retinopathy below about 6% (42 mmol/mol) was negligible.

The NZSSD Working Party has therefore recommended that a value for HbA₁c of ≤40 mmol/mol (5.8%) be regarded as normal glucose tolerance, and a value ≥50 mmol/mol (6.7%) represents diabetes, with values 41–49 mmol/mol (5.9–6.6%) representing pre-diabetes or dysglycaemia. For asymptomatic people an HbA₁c of ≥50
mmol/mol (6.7%) on a second separate occasion is required to confirm the diagnosis of diabetes.

There is, to our knowledge, no evidence that guides what the interval between testing should be in patients who are truly asymptomatic and whose initial HbA1c is ≥50 mmol/mol (6.7%) when first screened. For patients very close to the cut point it would seem reasonable to offer an interval of lifestyle intervention before repeating the test as a ‘label’ of diabetes is currently a ‘lifetime’ one with many downstream effects.

It is acknowledged however that it is equally important that those patients with ‘true’ diabetes (i.e. repeated HbA1c ≥50 mmol/mol) are in fact promptly diagnosed so that appropriate screening for micro- and macrovascular complications and intervention programmes can begin. The relationship of HbA1c and cardiovascular disease risk is continuous and all patients having screening for diabetes using the HbA1c should also have appropriate CVD risk assessment according to published guidelines (NZGG 2009 and 2011).

Point of care testing of HbA1c is unreliable for diagnosing diabetes and measurement of HbA1c must be done by a certified laboratory using the IFCC method.\textsuperscript{18}

Limitations of HbA1c in diagnosis—Like all laboratory tests the HbA1c has some limitations.\textsuperscript{24} Rarely, haemoglobinopathies can cause a falsely high or low HbA1c but most modern assays overcome this difficulty, although laboratory and clinical staff need to vigilant for potentially discrepant results.

Iron deficiency can falsely elevate HbA1c and must be recognised when diagnosing patients with diabetes using HbA1c alone. On the other hand, patients with increased red blood cell turnover (particularly haemolytic anaemia and chronic anaemia secondary to renal failure) will have a falsely low HbA1c. Furthermore, there is some evidence that individuals may glycate their haemoglobin at different rates to others with equivalent prevailing glucose values—‘high or low glycators’—with resulting higher or lower HbA1c respectively, potentially leading to a false positive diagnosis.\textsuperscript{25} However there is evidence also that those who are ‘high glycators’ do have an increased risk for retinopathy with equivalent glucose control versus normal subjects, suggesting that these patients have a higher retinopathy risk at lower prevailing glucose and thus diagnosing them with diabetes is not disadvantageous.\textsuperscript{26}

Ethnic differences in the rate of glycation of haemoglobin have been reported with black Americans having an HbA1c higher than non-black Americans with equivalent prevailing glucose.\textsuperscript{27} Data on ethnic differences on the rate of glycation in the New Zealand population are currently lacking.

Interpreting combined HbA1c and glucose measurements—A summary of how to interpret HbA1c and glucose screening results is shown in Table 3. If patients undergoing screening for diabetes have a fasting glucose as well as an HbA1c measured, then some patients will have discordant results – one value above and one below the cut point for diabetes diagnosis. Many studies have compared diabetes prevalence using an HbA1c versus OGTT or fasting glucose.\textsuperscript{28–32} Not surprisingly the prevalence of diabetes using these different definitions, is indeed different, and patients may have discordant results.
There is no truly correct figure as there is no “gold standard” for the diagnosis. The NZSSD Working Party has used a cut point for diabetes diagnosis for HbA1c of ≥50 mmol/mol that defines a significant retinopathy risk.\textsuperscript{10} This is equivalent to 6.7%, thus a higher threshold than the 6.5% set by ADA\textsuperscript{3} or WHO.\textsuperscript{5} The NZSSD rationale is to maximise the specificity for the diagnosis of diabetes. It may be argued that sensitivity is being sacrificed and cases of diabetes are being “missed”.

We would contend, however, that these individuals will be re-tested in 6–12 months and will likely enter a lifestyle programme where CVD risk factors are addressed. Although they will not acquire the diagnostic label of diabetes, nor enter an annual programme of microvascular complications screening, they are not really being “missed”.

For patients with discordant results of HbA1c and fasting glucose, it is likely that these values will be at or close to the cut points and therefore it is recommended that lifestyle advice be given, and after an interval a repeat test (usually the HbA1c) should be done to confirm or refute the diagnosis. Again, there is no evidence to guide how long this interval should be, but given the life span of the red blood cell, an interval of at least 2–3 months seems logical.

The relationship between prevailing HbA1c and estimated average glucose has been examined in a number of studies, usually finding a wide range for the glucose equivalent of a given HbA1c.\textsuperscript{9} At this stage the wider international community has not endorsed calculation of an estimated average glucose from HbA1c and thus for the moment in New Zealand, HbA1c will only be reported in mmol/mol without a comment made regarding how this might relate to estimated average glucose.

Table 3. What to do following a screening test for Type 2 diabetes
(www.nzssd.org.nz)

<table>
<thead>
<tr>
<th>Result</th>
<th>Action</th>
<th>Why</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symptomatic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HbA1c ≥50 mmol/mol and, if measured, Fasting glucose ≥7.0 mmol/L Or Random blood glucose ≥11.1 mmol/L</td>
<td>No further tests required</td>
<td>Diabetes is confirmed</td>
</tr>
<tr>
<td><strong>Asymptomatic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HbA1c ≥50 mmol/mol and, if measured, Fasting glucose ≥7.0 mmol/L Or Random glucose ≥11.1 mmol/L</td>
<td>Repeat HbA1c (or a fasting plasma glucose if HbA1c likely to be unreliable)</td>
<td>Two results above the diagnostic cut offs, on separate occasions are required for the diagnosis of diabetes*</td>
</tr>
<tr>
<td>HbA1c 41–49 mmol/mol and, if measured, Fasting glucose 6.1–6.9 mmol/L</td>
<td>Advise on diet and lifestyle modification. Repeat HbA1c after 6–12 months</td>
<td>Results indicate ’pre-diabetes’ or impaired fasting glucose*</td>
</tr>
<tr>
<td>HbA1c ≤40 mmol/mol and, if measured, Fasting glucose ≤6 mmol/L</td>
<td>Retest HbA1c at intervals as suggested in cardiovascular risk factor guidelines</td>
<td>This result is normal</td>
</tr>
</tbody>
</table>

* When HbA1c and fasting plasma glucose are discordant with regard to diagnosis of diabetes, repeat testing of the HbA1c at an interval of 3–6 months is recommended. If the second result is still discordant with the first, then subsequent repeat testing at intervals of 3–6 months is recommended. Patients with discordant results are likely to have test results near the diagnostic threshold.
**HbA1c targets in patients with established diabetes**

A further advantage of using HbA1c as the preferred diagnostic test for diabetes is that a baseline value is established for setting treatment targets. For patients with established diabetes, treatment targets for HbA1c must always be individualised based on many factors that include life expectancy and number of comorbidities. It should not normally be measured more frequently than 3 monthly. **Table 2** lists suggested targets with appropriate commentary about interpretation of the values. These have been agreed to by New Zealand based laboratories and many are now providing automatic comment on all HbA1c results. These tables are also readily available at [www.nzssd.org/HbA1c](http://www.nzssd.org/HbA1c).

**Unresolved issues**

During these deliberations a number of issues and principles related to the diagnosis of diabetes have arisen that are not adequately addressed by current international criteria. These include the lack of any definition or requirement for chronicity (sustained abnormality) of hyperglycaemia for the diagnosis of diabetes in contrast to raised blood pressure \(^{33}\) or chronic kidney disease, \(^{34}\) the only requirement being for two separate diagnostic readings when the patient is asymptomatic. The latter requirement is frequently not understood or is ignored.

Many authorities query the use of a dichotomous ‘cut-point’ of either HbA1c or glucose in what is a continuous variable with evidence of a progressive relationship between glycaemia and cardiovascular risk, \(^{20-23}\) though the relationship with microvascular disease does appear to have a threshold as discussed above. \(^{10}\)

There is also currently no mechanism to ‘undo’ a diagnosis of Type 2 diabetes once made; a recent study shows that at least temporary reversal is possible with extreme calorie restriction. \(^{35}\) The dramatic response of hyperglycaemia to marked weight loss, exemplified by bariatric surgery, has also led to the question of how ‘remission’ (or even “cure”) might be defined, \(^{36}\) concepts that are essentially not considered in previous international diagnostic criteria. Additionally some patients develop short term reversible hyperglycaemia when exposed to steroids or other drugs.

At the present time, HbA1c is not endorsed for the diagnosis of gestational diabetes mellitus, given that diagnostic thresholds are lower and cannot be similarly applied in pregnancy due to alterations in red cell turnover and other factors. Different outcome measures, eg macrosomia are also pertinent and further research is required before HbA1c can be endorsed for diagnosis in this context.

Premature or incorrect diagnosis of diabetes can lead to unnecessary anxiety for the patient and significant insurance and employment issues as well as involve unwarranted and costly medical procedures such as regular retinal screening.
Conclusions

- In New Zealand laboratories HbA1c is now only reported in SI units of mmol/mol.
- HbA1c is now recommended as the preferred test to diagnose diabetes in most circumstances.
- The requirement for a second positive test in asymptomatic individuals is retained.
- An HbA1c ≥50 mmol/mol (repeated on a second occasion in asymptomatic patients) is diagnostic of diabetes and a value ≤40 mmol/mol represents normal glucose tolerance.
- For patients with an initial HbA1c result of 41–49 mmol/mol, cardiovascular risk assessment and lifestyle interventions are recommended with repeat HbA1c screening in 6–12 months.
- For patients whose HbA1c is ≤40 mmol/mol, repeat screening (including for CVD risk) at intermittent intervals is recommended as per published guidelines.

Competing interests: None known.

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7. www.nzssd.org.nz


