# Post-meal blood glucose testing in adults with diabetes: Consensus recommendations

Antonio Ceriello, Sue Cradock, Rita Forde, Martin Hadley-Brown, Eric Kilpatrick, Deirdre Kyne Grzebalski, Rebecca Skelding, Maureen Wallymahmed

**Management of $HbA_{1c}$ and fasting plasma glucose levels are key components of the management of both type 1 and type 2 diabetes. However, a growing weight of evidence suggests that the management of post-meal blood glucose (PMBG) levels is also an important element of glycaemic control. Given this, healthcare professionals should be aware of how best to advise people with diabetes to implement PMBG testing. Based on the available evidence and their collective experience, the authors of this UK and Ireland consensus statement present practical recommendations regarding PMBG testing in people with either type 1 or type 2 diabetes.**

An experienced group of diabetes specialists with a range of medical, chemical pathology and nursing backgrounds met in London on 5 March 2009. The group's aim was to take the recommendations made in the International Diabetes Federation (IDF) *Guideline for Management of Post-meal Glucose* (IDF, 2007) to the next stage of clinical use for all healthcare professionals working in diabetes. While the IDF Guideline stressed the importance of post-meal blood glucose (PMBG) testing, it did not offer any practical advice for its implementation. Focusing on Question 4 of the IDF guideline – "What are the targets for post-meal glycaemic control and how should they be assessed?" – the group agreed on practical advice for the implementation of PMBG testing in the clinical setting. It is envisaged that this practical guide will help healthcare professionals encourage people with diabetes to monitor their PMBG levels appropriately, as part of their glycaemic management, in order to improve overall glycaemic control.

**Article points**

1. While the IDF *Guideline for Management of Post-meal Glucose* stressed the importance of post-meal blood glucose (PMBG) testing, it did not offer any practical advice for its implementation.
2. A Consensus Group agreed on practical advice for the implementation of post-meal blood glucose testing in the clinical setting.
3. It is envisaged that this practical guide will help healthcare professionals encourage people with diabetes to monitor their PMBG levels appropriately.

**Key words**

- Post-meal testing
- Type 1 diabetes
- Type 2 diabetes

Full author details can be found at the end of the article.

**Page points**

1. The recommendations made in this consensus are based on a review of the scientific evidence where available and, where not, on the clinical experience of the group. They are, as with all guidelines, not expected to replace clinical judgement.
2. A number of studies now show that post-meal glucose, as with fasting plasma glucose, makes a significant contribution to overall glycaemic control, and that specifically targeting post-meal glucose, in addition to fasting glucose, can help optimise $HbA_{1c}$.

The Consensus Group identified five groups of people with diabetes in the clinical circumstances where current NICE guidance suggests blood glucose testing should be available:

- Type 1 diabetes.
- Type 2 diabetes (on insulin).
- Type 2 diabetes (on oral hypoglycaemic agents with or without insulin).
- Type 2 diabetes (on diet alone).
- Gestational diabetes.

It was agreed that the latter group would not be considered by this consensus statement given that there are already clear NICE guidelines on the use of PMBG testing in this population (NICE, 2008a).

Recommendations made by the Consensus Group are given on:

1. Timing of PMBG testing in these patient groups.
2. Frequency of PMBG testing.
3. Target blood glucose levels.

Clinical practice examples of when PMBG testing might be particularly useful are also provided. The recommendations made in this consensus are based on a review of the scientific evidence where available and, where not, on the clinical experience of the group. They are, as with all guidelines, not expected to replace clinical judgement.

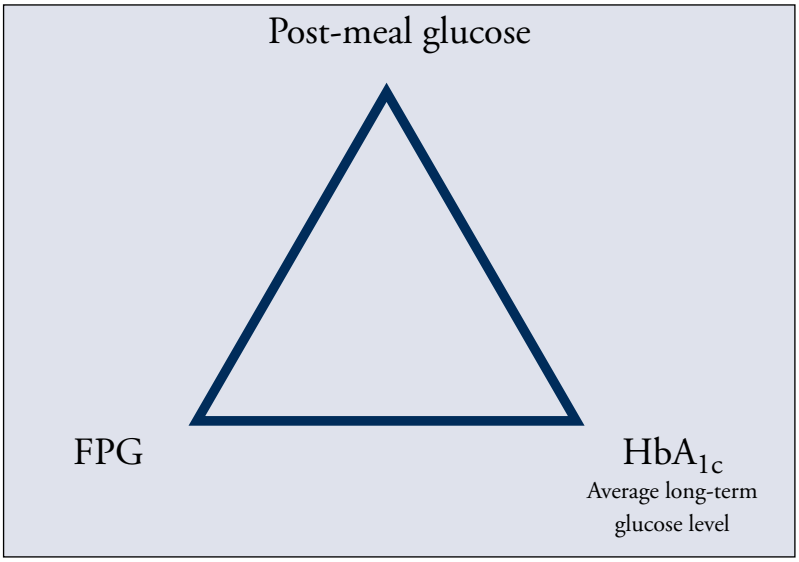


*Figure 1. "Glucose triad" of diabetes management (Ceriello and Colagiuri, 2008). FPG=fasting plasma glucose.*

The Consensus Group emphasises that, when considering any blood glucose self-monitoring in people with diabetes (pre- or post-meal blood glucose testing), for testing to make any difference to outcomes and be of any value, it must lead to an action. As such, the group only recommends testing in situations where either those with diabetes or a healthcare professional will review the result and take appropriate action.

## Should PMBG testing be performed in people with all types of diabetes?

Glycaemic control remains fundamental to the successful management of diabetes (Woo et al, 2008). Until recently, the predominant focus of therapy in people with diabetes has been on lowering $HbA_{1c}$ levels, with a strong emphasis on fasting plasma glucose (FPG; Nathan et al, 2006; Ceriello and Colagiuri, 2008). Although control of fasting hyperglycaemia is clearly necessary (DECODE Study Group, 1999; DECODE Study Group and European Diabetes Epidemiology Group, 2003; Woerle et al, 2007; Ceriello and Colagiuri, 2008), it is usually insufficient to obtain optimal glycaemic control. A growing weight of evidence suggests that reducing PMBG excursions is as important (DECODE Study Group, 1999) or possibly more important, for achieving $HbA_{1c}$ goals (Ohkubo et al, 1995; Hanefield et al 1999; 2004; Levitan et al, 2004; Shiraiwa et al, 2005).

Data from a number of studies show that PMBG, as with FPG, makes a significant contribution to overall glycaemic control, and that specifically targeting PMBG, in addition to FPG, can help optimise $HbA_{1c}$ (Monnier et al, 2003; 2007; Woerle et al, 2007; Woo et al, 2008). Thus, targeting both PMBG and FPG is an important strategy for achieving optimal glycaemic control (IDF, 2007). This introduces the concept of the "glucose triad" of diabetes management (*Figure 1*; Ceriello and Colagiuri, 2008).

It has been acknowledged by the IDF that post-meal hyperglycaemia is harmful and should be addressed (IDF, 2007; Ceriello and Colagiuri, 2008). Indeed, the use of self-monitoring of blood glucose (SMBG) in type 1 and type 2 diabetes, including PMBG

testing, is now supported by various guideline recommendations (American Diabetes Association [ADA], 2006; American Association of Clinical Endocrinologists [AACE], 2007; IDF, 2007; Canadian Diabetes Association [CDA], 2008; NICE, 2004; 2008b). PMBG testing is an essential monitoring strategy to assess and help achieve post-meal glucose targets (IDF, 2007; AACE, 2007; ADA, 2009). Furthermore, treatment strategies should be implemented that lower PMBG in people with post-meal hyperglycaemia (IDF, 2007).

In addition to considering the benefits of PMBG testing on overall glycaemic control, the recent 10-year follow up of the UK Prospective Diabetes Study (UKPDS) in type 2 diabetes (Holman et al, 2008) and the results of the Diabetes Control and Complications Trial (DCCT Research Group, 1993; Nathan et al, 2005), together with expanding understanding of the "metabolic memory" in both type 1 and type 2 diabetes, should strengthen our drive for earlier and tighter control of blood glucose across our diabetes populations in order to try to minimise the risk of developing long-term complications (Ceriello et al, 2009).

After consideration of this evidence, together with their clinical experience of PMBG testing in various groups of people with diabetes, the Consensus Group makes the following recommendations.

***Should PMBG testing be performed in people with all types of diabetes?***

- PMBG is an integral part of the "triad" of glycaemic control in type 1 and type 2 diabetes, together with FPG and $HbA_{1c}$; consequently, the Consensus Group feels that PMBG testing has a valuable role in most people with diabetes.
- Optimal glycaemic control is ideally achieved early on following diagnosis of type 1 or type 2 diabetes, and should be maintained within tight limits for optimal patient outcome (DCCT Research Group, 1993; Nathan et al, 2005; Holman et al, 2008). However, due to the limitations of some therapeutic options, this may not be achievable in all individuals, and care should always be considered to manage people with the condition within the limits of maximal safety.

## What is the optimum blood glucose target and post-meal time-point for PMBG testing?

PMBG levels rarely rise above 7.8 mmol/L in people with normal glucose tolerance, and typically return to basal levels 2–3 hours after food ingestion (Polonsky et al, 1988; ADA, 2001; Jovanovic, 2001). The scientific validity of these recommendations has recently been confirmed in a study using continuous glucose monitoring, which showed that people without diabetes almost never go beyond this target level of glycaemia (7.8 mmol/L; Mazze et al, 2008). For this reason, the IDF and other organisations define normal glucose tolerance as <7.8 mmol/L, 2 hours following ingestion of a 75 g load of glucose (AACE, 2003; IDF, 2006; ADA, 2007).

The 2-hour time-point for measurement conforms to guidelines published by many of the leading diabetes organisations and medical associations (Nathan et al, 2006; AACE, 2007; Rydén et al, 2007; IDF, 2007; CDA, 2008; ADA, 2009). In addition, the 2-hour measurement may, in the Consensus Group's opinion, be the safest time-point for people treated with insulin, particularly in those relatively new to insulin therapy or in those who have received insufficient education. Such patient groups may respond inappropriately to additional insulin boluses if raised 1-hour PMBG levels are measured, as their initial bolus insulin may not have taken full effect ("insulin stacking"), which can lead to severe hypoglycaemia (IDF, 2007).

After consideration of this evidence, together with their appreciation of the need to encourage tighter glycaemic control, the Consensus Group makes the following recommendation.

***What is the optimum blood glucose target and post-meal time-point for PMBG testing?***

- The PMBG testing target of <7.8 mmol/L taken 2 hours after a meal is the ideal target and time-point in most, but not all, people with

**Page points**

1. Post-meal blood glucose is an integral part of the "triad" of glycaemic control in type 1 and type 2 diabetes, together with FPG and $HbA_{1c}$; consequently, the Consensus Group feels that PMBG testing has a valuable role in most people with diabetes.
2. Optimal glycaemic control is ideally achieved early on following diagnosis of type 1 or type 2 diabetes, and should be maintained within tight limits for optimal patient outcome. However, due to the limitations of some therapeutic options, this may not be achievable in all individuals, and care should always be considered to manage people with the condition within the limits of maximal safety.

**Page points**

1. The exact role of post-meal blood glucose (PMBG) testing in optimal glucose control in any individual will be determined by the goals of treatment resulting from an individualised care plan approach that takes into account duration of diabetes and likely risks of lowering any aspect of the glucose triad.
2. The frequency and timing of PMBG testing, as part of an overall self-monitoring strategy, will be most effective when determined by a clear problem-solving approach. What is the problem? How will PMBG help to address that problem? When and how often does PMBG testing need to occur for this problem to be identified and resolved?

type 1 or type 2 diabetes. However, this should always be achieved within the limits of maximal safety in order to avoid hypoglycaemia.

## What are the options, challenges and limitations for PMBG testing in clinical practice?

The Consensus Group acknowledges that achieving a target of <7.8 mmol/L with 2-hour PMBG testing is an ideal scenario in most people with type 1 and type 2 diabetes. However, the group recognises the challenge that this stringent target brings to clinical practice, and so offers practical steps to determine how this might be best achieved, within the limits of maximal safety. Below, the group provides an indication of the circumstances in which PMBG testing might be an important part of assessing and maintaining glycaemic control in clinical practice, along with its exact role and frequency.

### *Exact role and frequency of PMBG in clinical practice*

- The exact role of PMBG testing in optimal glucose control in any individual will be determined by the goals of treatment resulting from an individualised care plan approach that takes into account duration of diabetes and likely risks of lowering any aspect of the glucose triad.
- The frequency and timing of PMBG testing, as part of an overall self-monitoring strategy, will be most effective when determined by a clear problem-solving approach. What is the problem? How will PMBG help to address that problem? When and how often does PMBG testing need to occur for this problem to be identified and resolved?
- PMBG testing, as an additional strategy to pre-meal blood glucose testing, will help both the individual with diabetes and their healthcare professional to identify and review:
  1. The contribution of post-meal hyperglycaemia to a raised $HbA_{1c}$.
  2. The effect of carbohydrate (CHO)-rich meals on post-meal hyperglycaemia, thereby offering an option to reduce the CHO content of meals as a first-line option.
  3. The appropriate next oral hypoglycaemic agent to prescribe.
  4. The appropriate insulin regimen to prescribe.
- Recognise that blood glucose testing strategies are not about testing pre- and post-meal all of the time; periodic testing may be the correct option for many. In the Consensus Group's experience, unnecessary long-term PMBG testing could lead to loss of motivation in some people and be a waste of resources.
- Do not be afraid to alter the frequency, or start and stop testing, as needed, in each individual, dependent on the reason for PMBG testing
- Intensify PMBG testing in all well-recognised clinical situations where needed, e.g. alteration of therapy, raised $HbA_{1c}$ levels, sickness.

## Clinical practice tips for PMBG testing in all people with diabetes

Due to the desire of the Consensus Group to produce a practical tool for healthcare professionals, the group offers several clinical practice tips to assist healthcare professionals in

**Box 1. Achieving post-meal blood glucose testing targets in practice.**

- Four-point plan: pre- and post-meal blood glucose testing for two "key" (breakfast and evening) meals a day.
- Seven-point testing: pre- and post-meal blood glucose testing for three meals and bedtime.
- Agree the purpose of the testing strategy in partnership with the person with diabetes, and plan how the results will be used to make changes.
- The Consensus Group recognises the need for those with type 1 and type 2 diabetes to be offered a structured education programme (in line with NICE guidance) to provide the context and rationale for self-testing as part of supporting self-management in diabetes, and notes that post-meal blood glucose testing is often an integral part of this.

achieving the stringent PMBG testing target in their patients with diabetes (*Box 1*).

### *Clinical practice tips for PMBG testing in people with diabetes*

- PMBG testing is an important measure of glycaemic control for those with poorly controlled type 1 and type 2 diabetes where indicated (as determined by $HbA_{1c}$ level) as the PMBG level contributes to the raised $HbA_{1c}$ level (McCarter et al, 2006; Woerle, 2007).
- Even in those with well-controlled type 2 diabetes (according to $HbA_{1c}$), PMBG testing on a periodic basis (e.g. 2 days of four-point testing every 6 months) will be valuable to assess the PMBG level and possible risk (see *Box 1*).

## Type 1 diabetes

The Consensus Group acknowledges that, in clinical practice, PMBG testing is an important aspect of control in type 1 diabetes, including in people with poorly controlled type 1 diabetes (according to $HbA_{1c}$). Given the potential for insulin-induced hypoglycaemia, some medical organisations recommend that people treated with insulin perform SMBG at least three times per day (IDF, 2007; ADA, 2007; CDA, 2008) and should include both pre- and post-meal measurements.

To assist healthcare professionals in everyday clinical practice, the Consensus Group has identified specific clinical situations in which more intensive or frequent PMBG testing may be particularly useful in people with type 1 diabetes. The group recommends it in people who:

- Are carbohydrate counting.
- Are using insulin pumps, or have multiple daily injection regimens.
- Start or change insulin therapy, until optimal control is achieved.
- Want to determine the effect of foods or drinks on glycaemic control.
- Have a care plan consultation, performed 1–2 weeks prior to this, to assess control.
- Need re-education at any time-point as part of a structured education programme.

## Type 2 diabetes – general recommendations

Results of the recently published UKPDS 10-year follow-up of intensive glucose control in type 2 diabetes confirmed the benefit of early intensive control of glucose in type 2 diabetes (Holman et al, 2008). Furthermore, Monnier et al (2003) confirmed that post-meal hyperglycaemia is an important aspect of glycaemic control in type 2 diabetes, particularly at lower $HbA_{1c}$ levels.

NICE recommends considering PMBG testing if $HbA_{1c}$ is above target and pre-meal levels are at a good level, aiming for a target of >8.5 mmol/L in type 2 diabetes (NICE, 2008b). Data show that there is no lower limit, short of normoglycaemia, where any benefits associated with improved glycaemic control, are lost (i.e. the lower the better; IDF, 2007) and so the Consensus Group strongly believes that encouraging more stringent targets can only be beneficial to long-term outcome in people with type 2 diabetes. The need to tailor these targets to individuals is as important in people with type 2 diabetes as it is in those with type 1 diabetes.

The Consensus Group agrees that those with type 2 diabetes taking insulin in basal–bolus regimens should be considered as for those with type 1 diabetes for the purposes of PMBG testing; those with type 2 diabetes taking basal insulin only should perform PMBG testing, with careful consideration given to the recommended frequency. With an increasing number of people with type 2 diabetes being commenced on insulin in combination with oral hypoglycaemic agents due to the increasing evidence of the benefits of this combination (NICE, 2008b), this patient group will expand and so is an important one in which to consider the utility of PMBG testing.

## Frequency and timing of PMBG testing in type 2 diabetes in clinical practice

The Consensus Group believes that, in clinical practice, PMBG testing is an important aspect of control in type 2 diabetes, including in people with well-controlled type 2 diabetes (according to $HbA_{1c}$). Existing guidelines

**Page points**

1. The Consensus Group acknowledges that, in clinical practice, PMBG testing is an important aspect of control in type 1 diabetes, including in people with poorly controlled type 1 diabetes (according to $HbA_{1c}$).
2. Results of the recently published UKPDS 10-year follow-up of intensive glucose control in type 2 diabetes confirmed the benefit of early intensive control of glucose in type 2 diabetes.
3. The Consensus Group agrees that those with type 2 diabetes taking insulin basal–bolus regimens should be considered as for those with type 1 diabetes for the purposes of PMBG testing; those with type 2 diabetes taking basal insulin should perform PMBG testing, with careful consideration given to the recommended frequency.

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1. Well-informed and motivated patients are more successful in obtaining and maintaining good control of their risk factors, resulting in reduced cardiovascular risk and slower progression of microvascular disease.

state that the frequency and timing of SMBG in type 2 diabetes should be dictated by the particular needs and goals of the individual, (CDA, 2008; ADA, 2009) and should include both pre- and post-meal measurements.

To assist healthcare professionals in everyday clinical practice, the Consensus Group has identified specific clinical situations in which more intensive PMBG testing may be particularly useful in people with type 2 diabetes (*Box 2*).

## The importance of structured education in PMBG testing

Clinical studies and experience have consistently shown that implementing a structured education tool with specialist advice leads to the most successful outcomes in patient self-monitoring (Schwedes et al, 2002; Welschen et al, 2005; Jansen, 2006; Moreland et al, 2006). Well-informed and motivated people with diabetes are more successful in obtaining and maintaining good control of their risk factors, resulting in reduced cardiovascular risk and slower progression of microvascular disease (Rachmani et al, 2005). For this reason, guidelines advocate educational programmes to support self-monitoring (IDF, 2007; NICE, 2008b). The Consensus Group strongly believes that PMBG testing is a valuable information and

**Box 2. Clinical situations in which more intensive or frequent PMBG testing may be particularly useful in people with type 2 diabetes.***

| On insulin | On oral hypoglycaemic agents ± insulin | On diet alone |
|---|---|---|
| Not yet started insulin therapy, to help determine choice of insulin regimen and dose. | To determine overall control of disease, e.g. performed 1–2 weeks prior to a care planning consultation. | To see the effect of certain foods on glycaemic control, to help inspire positive lifestyle changes. |
| Just started insulin, to help adjust dose or regimen if PMBG level is above target. | About to start insulin or insulin secretagogues, to determine the exact regimen and dose. | To review how weight loss strategies, exercise and activities effect the glucose triad over time. |
| Using basal–bolus insulin regimens, to determine post-meal glycaemic control and requirement for bolus insulin dose changes. | To assess the effect of food/lifestyle changes on PMBG levels. | To help determine whether to commence oral hypoglycaemic agent treatment. |
| To review the contribution of PMBG to the picture of control throughout the day/week before making insulin dose changes. | On sulphonylureas, to help recognise and prevent hypoglycaemia. | To help confirm control using random PMBG testing, e.g. over 2–3 days at certain time-points, e.g. in illness, starting other treatments, e.g. steroids. |
| | To help identify signs of hypoglycaemia, since many do not recognise them and are afraid to report them due to potential consequences, e.g. loss of driving licence. | |
| | To assess sufficiency of oral hypoglycaemic agent dose. | |
| | To help determine choice of second- or third-line oral hypoglycaemic agent when $HbA_{1c}$ is above target. | |

* Readers should note that structured education is crucial to the effectiveness of all glucose monitoring – see "The importance of structured education in PMBG testing" section. PMBG = post-meal blood glucose.

educational tool for people with diabetes and healthcare professionals to assess and maintain control over the condition.

For any blood glucose monitoring to be cost- and clinically effective, those using it (both people with diabetes and their healthcare professionals) should:

- Understand the role of testing in the glucose triad.
- Understand and show competence in the purpose and value of testing.
- Be able to analyse and interpret the results (both high and low readings).
- Be able to decide what action to take.
- Be able to take that action.
- Know how to review results, including when to be followed-up.

At present, most people with diabetes are taught, at a minimum, how to use the blood glucose testing equipment. However, increased appreciation of the value of being skilled in the appropriate use of this valuable tool is now encouraging many specialist teams to follow the NICE guidance and only introduce testing as part of an overall education programme for people with type 2 diabetes. This may require a review of current approaches for many teams, but is strongly encouraged.

After consideration of this evidence, together with their own experience of structured education programmes led by diabetes specialists, the Consensus Group makes the following comments:

- PMBG testing can be seen as a valuable information and educational tool for people with diabetes and healthcare professionals to assess and maintain control of the condition, within a structured education programme.
- Structured education, supported by well-trained and experienced healthcare professionals, is essential to the clinical and cost-effectiveness of all glucose monitoring, including PMBG testing.
- Structured education should include instruction in interpretation of results, appropriate action and follow-up.
- The Consensus Group acknowledges that the introduction of easier-to-use blood glucose meters that specifically aid PMBG testing and couplet testing (FPG and PMBG) means that self-monitoring, both pre- and post-meal, is relatively simple for people with diabetes.

## Conclusion

The recommendations presented in this article are intended to be of assistance to healthcare professionals in encouraging people with diabetes to monitor their PMBG levels appropriately. It is hoped that this guidance will be useful in the practical implementation of the IDF *Guideline for Management of Post-meal Glucose* (IDF, 2007). As with all blood glucose monitoring, the Consensus Group emphasises that for PMBG to make a difference to outcomes, it needs to be implemented as part of an overall education programme and lead to appropriate action. ■

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### Author details

Antonio Ceriello is Professor of Diabetes and Metabolic Diseases, Warwick Medical School, Warwick. Sue Cradock is a Nurse Consultant, Queen Alexandra Hospital, Portsmouth. Rita Forde is an Advanced Nurse Practitioner, Mater Hospital Diabetes Day Centre, Dublin. Martin Hadley-Brown is a GP, Thetford, Norfolk. Eric Kilpatrick is Honorary Professor in Clinical Biochemistry, Hull Royal Infirmary and Hull York Medical School, Hull. Deirdre Kyne Grzebalski is Clinical Nurse Leader, Newcastle Diabetes Centre, Newcastle. Rebecca Skelding is a Clinical Nurse Specialist – Diabetes, University Hospitals Birmingham NHS Foundation Trust, Birmingham. Maureen Wallymahmed is a Nurse Consultant, University Hospital of Aintree, Liverpool.

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### Page points

1. Post-meal blood glucose (PMBG) testing can be seen as a valuable information and educational tool for people with diabetes and healthcare professionals to assess and maintain control of the condition, within a structured education programme.
2. Structured education, supported by well-trained and experienced healthcare professionals, is essential to the clinical and cost-effectiveness of all glucose monitoring, including PMBG testing.
3. Structured education should include instruction in interpretation of results, appropriate action and follow-up.

***"It is hoped that this guidance will be useful in the practical implementation of the IDF* Guideline for Management of Post-meal Glucose *(IDF, 2007)."***


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