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POSITION PAPER

Joint Australian Diabetes Society/Australian and New Zealand Society of Nuclear Medicine procedure guideline for FDG PET/CT imaging in patients with type 1 and type 2 diabetes

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Key words
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Abstract

^{18}F-fluorodeoxyglucose (FDG) positron emission tomography/computed tomography (PET/CT) is an established imaging technique for tumour diagnosis and staging, with imaging quality in people with diabetes closely linked to blood glucose concentration at the time of FDG injection. Adequate preparation is crucial for precise interpretation of PET/CT findings. However, protocols vary among institutions due to the availability of resources and expertise. This article summarises and provides commentary on a recently published de novo guideline, jointly endorsed by the Australian Diabetes Society and the Australian and New Zealand Society of Nuclear Medicine, which provides practical guidance for nuclear medicine staff managing people with type 1 and type 2 diabetes undergoing FDG PET/CT imaging. Recommendations were developed using an evidence-based approach informed by a comprehensive literature review and refined by a multidisciplinary expert panel. The guidelines outline standardised preparation protocols tailored to diabetes type, including advice on fasting, oral glucose-lowering medications, insulin regimens and insulin pump management. Adoption of these recommendations aims to optimise FDG PET/CT image quality while prioritising patient safety and improving FDG PET/CT scan quality for individuals with diabetes.

Background

^{18}F-fluorodeoxyglucose (FDG) positron emission tomography/computed tomography (PET/CT) is a widely used imaging modality, particularly for the evaluation of tumours, including initial staging, restaging, treatment monitoring and treatment planning. Appropriate patient preparation is important to optimise the image quality required for accurate interpretation of these studies. There are several considerations in the preparation of patients with diabetes that can influence image quality, including carbohydrate restriction, management of blood glucose levels and insulin administration.[1]

FDG is a radiolabelled glucose analogue that is actively transported into cells by glucose transporter proteins (GLUTs). In malignant and non-malignant processes such as inflammation, in which there is an increase in metabolic rate, cells increase the expression of GLUT receptors. This results in an increase in FDG uptake.[2]

Glucose competes with FDG for uptake into tumours or sites of inflammation, potentially reducing the sensitivity of the PET scan. Similarly, hyperinsulinaemia promotes uptake of FDG into non-target tissues such as

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muscle, resulting in altered biodistribution of radiotracer with high background FDG uptake, commonly referred to as a 'muscle scan'.

Different centres have introduced various fasting recommendations and insulin protocols based on local experience, noting the scarcity of evidence. While some centres require patients to fast from midnight for a morning scan, others opt to allow patients to consume an early breakfast with the usual morning insulin, ensuring a minimum of 4-h delay to FDG injection. The most recent European Association of Nuclear Medicine (EANM) procedure guideline published in 2015 outlines a preference for subcutaneous short-acting insulin injection to manage hyperglycaemia. FDG injection should be delayed for a minimum of 4 h following administration of subcutaneous short-acting insulin.[2] Some centres elect to use intravenous insulin because it may not be practical to delay the scan for the minimum 4 h required after subcutaneous insulin administration. There is some concern about the higher risk of hypoglycaemia and hypokalaemia with the administration of intravenous insulin, particularly in centres where staff experience and availability for glucose monitoring are limited.

Guidelines for managing diabetes before and after the FDG PET/CT scan are particularly important for patients with type 1 diabetes, to avoid the risk of hyperglycaemia, diabetic ketoacidosis and hypoglycaemia, all of which may lead to delayed scanning and associated morbidity. This article aims to summarise and provide commentary on the recently published de novo guideline, which was collectively endorsed by the Australian Diabetes Society (ADS) and the Australian and New Zealand Society of Nuclear Medicine (ANZSNM), titled Joint ADS/ANZSNM guideline for FDG PET/CT imaging in patients with type 1 and type 2 diabetes.[3] The guideline was made available in August 2024 and was presented at the Australian Diabetes Congress in August 2024. Access to the guideline is via the following link: https://www.diabetessociety.com.au/wp-content/uploads/2024/07/Joint-ADS-ANZSNM-guideline-for-FDG-PET-CT-imaging-in-patients-with-type-1-and-type-2-diabetes-1-August-2024.pdf.

Methods

This guideline was developed through a structured approach combining multidisciplinary expert consensus and a targeted literature review. A multidisciplinary expert writing group, consisting of nuclear medicine specialists, endocrinologists, pharmacists and nuclear medicine technologists, was engaged in discussions to ensure the recommendations were clinically relevant and practical for implementation. All potential conflicts of interest were declared, with none considered to influence the recommendations.

A targeted search of PubMed, Scopus and the Cochrane Library was undertaken using MeSH and free-text terms relating to diabetes, glycaemic management and FDG PET/CT patient preparation. Of 184 records identified, 174 were excluded following title and abstract screening, leaving 10 guidelines for full review.[2,4–12] Three provided specific recommendations on glucose management before FDG PET/CT.[2,9,12] Due to the limited high-quality evidence within these guidelines, a formal evidence-grading framework (e.g. GRADE) was not applied. Instead, references supporting each guideline were examined and recommendations from existing sources were synthesised using a narrative approach, integrated with expert opinion from our multidisciplinary working group.

Draft recommendations were prepared, discussed within the full group and refined through iterative consensus. The final guideline underwent stakeholder review before endorsement by the ADS and the ANZSNM.

Results

A summary of the guideline document is set out below. Key general principles are highlighted, including several important steps in preparation, pre-scan instructions and glucose management.[3]

Preparation and calibration

Regular calibration of the glucometer used for monitoring glucose levels in the nuclear medicine department is essential for accurate results.

Pre-scan instructions (for all patients with diabetes)

- Patients should avoid vigorous exercise for 24 h before the scan.[1,2,13]
- Glucagon-like peptide-1 (GLP-1) and GLP-1/glucose-dependent insulinotropic polypeptide (GIP) receptor agonists should be continued as prescribed, but fasting from midnight could be considered due to potential effects on gastric emptying.[14]
- For insulin-treated patients, morning appointments are preferred over afternoon appointments.[2]
- When evaluating gastrointestinal lesions, or if there has been significant gastrointestinal uptake interfering with interpretation on previous PET studies, it may be beneficial to stop metformin 48 h before the scan.[6,15]
- For assessment of cardiac inflammation, e.g., sarcoidosis, patients should follow a high-fat/protein and very

low-carbohydrate diet for 24 h before the scan and fast from midnight to minimise physiological myocardial FDG uptake.[16,17]
- For complex cases, particularly those involving insulin treatment in patients with type 1 diabetes who are at risk of hypoglycaemia and diabetic ketoacidosis, consider consulting with an endocrinologist.
- Some PET studies, such as those for neurofibromatosis or bladder cancer, may require two scans: one acquired immediately after the FDG uptake period and another ~4 h later. Patients fasting throughout the morning who omit their morning insulin can resume eating and administer their missed morning insulin after the first scan.
- Specific preparation instructions for individuals with type 1 and type 2 diabetes, including guidance on optimal scan scheduling, management of oral and non-insulin injectable agents and the use of insulin injections and insulin pump therapy are detailed in the Joint ADS/ANZSNM guideline for FDG PET/CT imaging in patients with type 1 and type 2 diabetes.[3]

Oral diabetes medications

- For individuals fasting from midnight for a morning scan, the usual morning oral medications are withheld.
- For individuals scheduled for an afternoon scan, the usual oral medications are advised to be taken with breakfast, noting that a minimum of a 4-h fast is required.

Glucose targets and management

- A blood glucose target of ≤12.0 mmol/L, or ≤10.0 mmol/L for brain imaging, before FDG injection is recommended.[4] However, this is a guide only, and individual centre protocols may vary.
- If hyperglycaemia cannot be controlled in the PET suite, consider consulting the patient's referrer, their endocrinologist or local endocrine service for further guidance.
- If a patient not previously diagnosed with diabetes has a fasting glucose of ≥7.0 mmol/L or a post-prandial glucose of ≥11.1 mmol/L, a new diabetes diagnosis is likely and should be communicated to the referring doctor.
- For patients with glucose levels >16.0 mmol/L upon arrival at the PET suite, it may be reasonable to reschedule the scan and recommend a referral to their endocrinologist or local endocrine service for advice.
- Upon arrival at the PET suite, the patient's glucose level should be checked and the recommendations outlined in Figure 1, followed.

Hypoglycaemia management

If a patient's glucose level is <4.0 mmol/L, administer 150 mL of clear apple juice or lemonade. Recheck the glucose level after 15 min. If it remains <4.0 mmol/L, repeat management until the glucose level is ≥4.0 mmol/L.

In the event of hypoglycaemia, consider rescheduling the PET scan to another day and allow the patient to eat. A PET scan performed soon after hypoglycaemia may be technically suboptimal. Some centres may choose to delay the scan for 6 h if the patient has been treated for hypoglycaemia.

Hyperglycaemia management

If the patient's glucose is >12.0 mmol/L, a dose of subcutaneous or intravenous short-acting insulin may be administered to lower the glucose level to the target range before FDG injection. Patients using an insulin pump can administer a correction insulin dose via their pump.

Suggested regimens of subcutaneous short-acting insulin doses for patients with type 2 diabetes and type 1 diabetes are provided in Tables 1–3. FDG injection should be delayed for a minimum of 4 h following administration of subcutaneous short-acting insulin.

Alternatively, intravenous insulin can be administered according to a local protocol, which should be formulated with endocrinology input. This method should be used cautiously in patients with renal impairment or a body mass index <25.0 kg/m^2 due to a higher risk of hypoglycaemia. Once intravenous insulin has been administered, a medical officer must be present until the PET scan has been completed. Capillary glucose levels should be monitored every 15 min to ensure they have reached the lowest point (the nadir level) and are starting to rise before the FDG injection. Achieving the nadir glucose level ensures minimal impact of exogenous insulin on FDG distribution. If there is any uncertainty about the nadir glucose level, wait an additional 15 min before checking again. Should hypoglycaemia occur following insulin administration, it should be managed using oral or intravenous glucose or glucagon according to local hypoglycaemia treatment guidelines.

Post-scan instructions

- If the patient has fasted from midnight, they should check their glucose levels, eat breakfast if it was previously omitted and administer their usual morning diabetes medications (which were omitted).

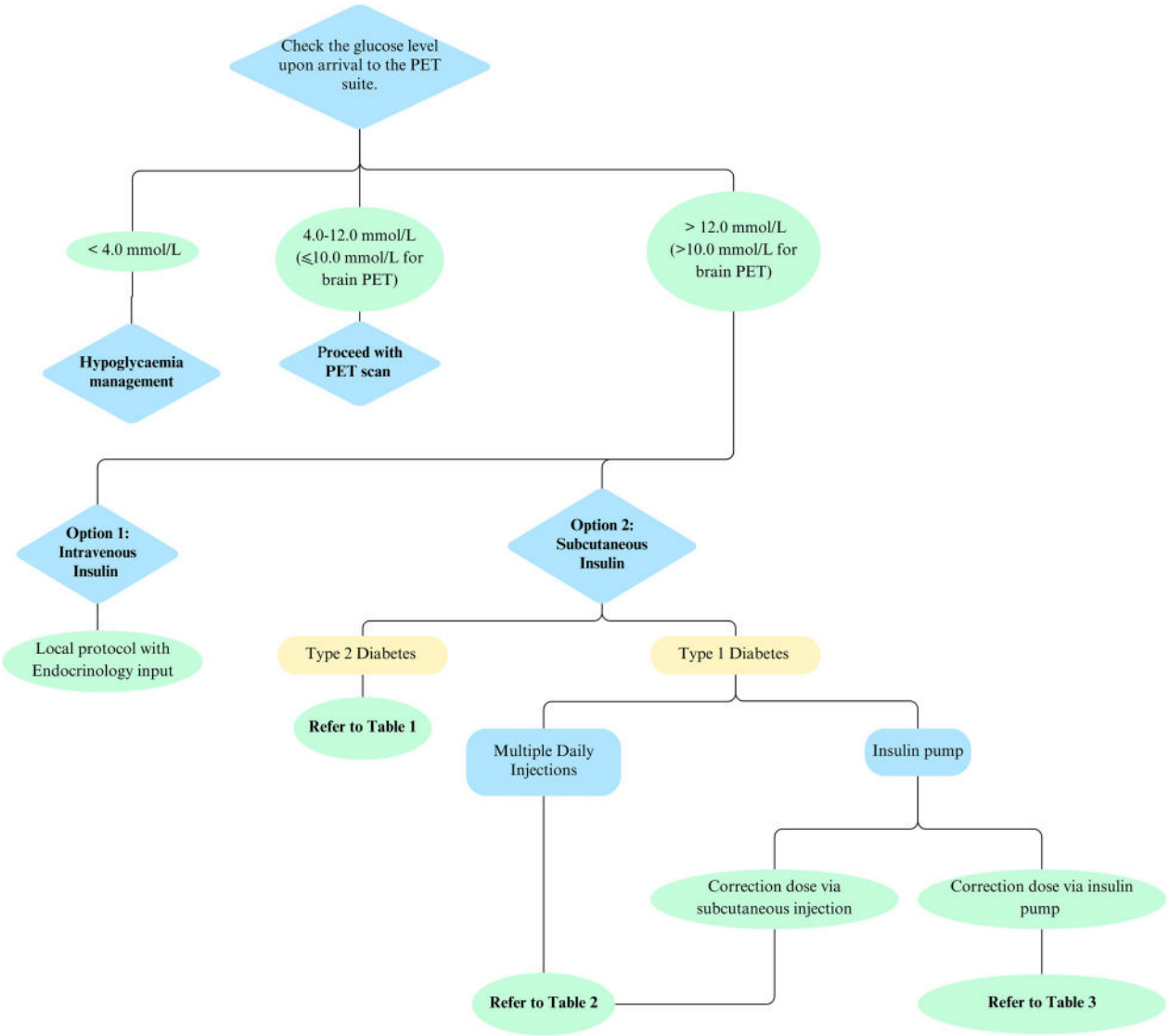

Figure 1 Flow chart for management of diabetes before FDG PET/CT imaging. CT, computed tomography; FDG, ^{18}F-fluorodeoxyglucose; PET, positron emission tomography.

- Patients should continue to monitor their glucose levels, ensuring >5.0 mmol/L before leaving the facility, particularly if they plan to drive.
- Patients with type 1 diabetes using an insulin pump should reattach their insulin pump and apply a new Flash Libre or continuous glucose monitoring system.

Discussion

In 2024, ~227 000 FDG PET scans were performed in Australia. While specific data on the number of scans conducted in patients with diabetes are not available, given that in 2021 >1.3 million Australians (5.3%) were living with diabetes and with increasing life expectancy among patients with diabetes, it is reasonable to assume that at least a proportionate number of PET scans involved individuals with diabetes. To date, there has been no published dedicated guideline for patients with diabetes undergoing FDG PET/CT imaging. The broad guidelines on FDG PET/CT imaging from different societies contain sections for patients with diabetes and they provide limited and variable directions on patient preparation, including adjustment of the patient's insulin regimen and management of hyperglycaemia. The 2010

Table 1 Recommended subcutaneous insulin doses in patients with type 2 diabetes

Glucose levels	Weight <60 kg	Weight 60–100 kg	Weight >100 kg
	Subcutaneous NovoRAPID, HumALOG or Apidra (units)		
10.1–12.0 (mmol/L)†	2‡	2‡	4‡
12.1–14.0 (mmol/L)	2	4	6
14.1–16.0 mmol/L	3	6	8
>16 mmol/L§	4	8	Contact endocrinology
Glucose monitoring: 2 and 4 h after subcutaneous insulin injection or if the patient is unwell.			
4 h following subcutaneous insulin injection			
Glucose level 4.0–12.0 mmol/L		Glucose level >12.0 mmol/L	
Proceed with PET scan (Target glucose ≤10.0 mmol/L for brain PET scans)	Consider rescheduling the scan. Depending on the circumstances, the nuclear medicine specialist may proceed with scanning. Please note: the cut-off of 12.0 mmol/L is a guide only.		

†Use for brain PET scan where the target glucose is ≤ 10.0 mmol/L. ‡Alternatively, encourage hydration and walking if the glucose level is 10.1 to 11.0 mmol/L. §Some centres may reschedule the scan if glucose is >16 mmol/L. PET, positron emission tomography.

Table 2 Recommended subcutaneous insulin doses in patients with type 1 diabetes

	Calculate the patient's total daily dose of insulin (the total amount of insulin a patient uses in 24 h)			
Total daily insulin	<30 units	31–50 units	51–100 units	>100 units
Glucose levels	Subcutaneous NovoRAPID, HumALOG or Apidra (units)			
10.1–12.0 mmol/L†	1‡	2‡	3‡	4‡
12.1–14.0 mmol/L	1	3	4	6
14.1–16.0 mmol/L	2	3	5	8
>16 mmol/L§	2	4	6	Contact endocrinology
Glucose monitoring: 2 and 4 h after subcutaneous insulin injection or if the patient is unwell.				
Ketones to be checked if glucose levels >15.0 mmol/L. A medical officer should be notified if ketone levels are >1.5 mmol/L.				
4 h following subcutaneous insulin injection				
Glucose level 4.0–12.0 mmol/L			Glucose level >12.0 mmol/L	
Remove any glucose monitoring devices. Proceed with PET scan. (Target glucose ≤10.0 mmol/L for brain PET scans)		Consider rescheduling the scan. Depending on the circumstances, the nuclear medicine specialist may choose to proceed with the scan.		

†Use for brain PET scan where the target glucose is ≤10.0 mmol/L. ‡Alternatively, encourage hydration and walking if the glucose level is 10.1 to 11.0 mmol/L. §Some centres may reschedule the scan if glucose is >16 mmol/L. PET, positron emission tomography.

EANM guidelines recommended aiming for normal blood glucose levels (<7.0 mmol/L) and rescheduling if glucose levels were ≥7.0 mmol/L.[4]

Other recommendations, including those from the Society of Nuclear Medicine and Molecular Imaging (SNMMI) and the National Cancer Institute, advised rescheduling if glucose levels are >8.3 to 11.1 mmol/L.[12,18] The revised 2015 EANM guidelines acknowledged that achieving normal glucose levels could be impractical, allowing scans to proceed if glucose was <11.0 mmol/L, with subcutaneous insulin administered to correct high glucose levels if necessary. The development of a personalised insulin calculator by Pattison *et al.* in 2015 demonstrated a reduced risk of hypoglycaemia associated with a standardised approach using intravenous insulin to lower elevated glucose levels to the target range before FDG injection.[5]

Patients with diabetes present unique challenges in FDG PET imaging due to altered glucose metabolism and the potential interaction between radiopharmaceutical uptake and antidiabetic medications. The implementation of this guideline is aimed to provide guidance to nuclear medicine staff by optimising glucose levels for PET scanning, minimising the adverse effects of insulin administration, improving diagnostic accuracy, ensuring patient safety and enhancing procedural efficiency. The guideline provides a flexible framework that individual centres can adapt to their own practices.

One of the key strengths of this guideline is standardisation of pre-procedural patient preparation tailored to the patient's diabetes subtype and treatment regimen. This enhances patient safety by providing clear practical recommendations on medication adjustments before the

Table 3 Recommendations for patients using insulin pump therapy

If glucose level is >12.0 mmol/L, the patient should be advised to administer a correction dose through their insulin pump.	
Glucose monitoring: 2 and 4 h after correction or if the patient is unwell.	
Ketones to be checked if glucose levels >15.0 mmol/L. A medical officer should be notified if ketone levels are >1.5 mmol/L.	
4 h following pump correction dose	
Glucose level 4.0–12.0 mmol/L	Glucose level >12.0 mmol/L
Remove the insulin pump and glucose-monitoring device. Proceed with PET scan.	Consider rescheduling the scan. Depending on the circumstances, the nuclear medicine specialist may proceed with scanning.
(Target glucose ≤10 mmol/L for brain PET scans)	Please note: the cut-off of 12.0 mmol/L is a guide only.

PET, positron emmission tomography.

FDG PET/CT scan, particularly in individuals with type 1 diabetes who are at an increased risk of adverse outcomes if insulin is inappropriately withheld. The omission of long-acting insulin or insulin pump therapy can precipitate diabetic ketoacidosis. Our guideline, therefore, aims to address existing gaps regarding the pre-scan standardised management of oral glucose-lowering medications, subcutaneous insulin and insulin pump therapy.

The recommendation for patients to withhold their usual morning oral diabetes medications, particularly sulfonylureas, if they fast for a morning scan is to ensure that the risk of hypoglycaemia is minimised. The recommendation for the patient to take their usual morning oral diabetes medications if the scan is scheduled in the afternoon and to have breakfast is to ensure good control of their glucose level on arrival to the PET suite. While sulfonylureas stimulate endogenous insulin secretion, there is a lack of evidence regarding a direct effect of this class of oral diabetes medications on FDG uptake.

Although intravenous insulin administration has been well studied for the correction of hyperglycaemia before FDG administration, only one study has evaluated the impact of subcutaneous short-acting insulin on FDG uptake.[19] In that study, the authors noted that their centre was not located near a hospital and therefore a subcutaneous insulin protocol was adopted to minimise the risk of hypoglycaemia, an approach that reflects concerns shared by many centres. They reported that FDG uptake was not affected when subcutaneous insulin was administered more than 4 h before imaging.[19] Our guideline is consistent with these findings and aligns with current recommendations.[2,9,20]

With respect to long-acting insulin, evidence is scarce, with a single case report having demonstrated no meaningful impact on FDG biodistribution.[21] While some protocols suggest that long-acting insulin should not be administered on the day of the scan, such an approach may compromise glycaemic stability and patient safety, particularly in individuals with type 1 diabetes.[2] Furthermore, there is no evidence regarding whether insulin resistance and supraphysiological basal insulin doses influence FDG biodistribution more than lower insulin doses used in leaner individuals with type 1 diabetes.

Another important strength of this guideline is the provision of practical instructions for individuals with type 1 diabetes, with specific guidance for individuals using continuous subcutaneous insulin infusion and continuous glucose monitoring systems. This is an area where previous guidelines have provided limited advice, deferring decisions to treating clinicians who may be unaware that a PET scan is scheduled. The most recent EANM guideline recommends discontinuation of insulin pumps at least 4 h before FDG administration,[2] whereas the earlier guideline advised maintaining the pump in basal mode.[9] This shift likely reflects concerns that rapid-acting insulin could theoretically affect FDG uptake. However, the doses administered are small compared with the large bolus doses evaluated in published studies and are intended to mimic physiological basal insulin levels.[19] There is no published evidence that basal pump delivery affects imaging quality and, given the substantial of diabetic ketoacidosis associated with pump cessation, we strongly recommend that patients continue their pump in basal mode for morning scans until just before they have their PET scan. If boluses are required for breakfast or for correction of elevated glucose levels, a period of >4 h is recommended before FDG injection. Further data regarding the management of insulin pump therapy in the context of FDG PET/CT imaging are needed to inform future recommendations. It is also important to recognise that with emerging automated insulin delivery technologies, the impact of algorithm-driven autocorrection doses on FDG uptake remains uncertain.

Although individual institutions may have established protocols for intravenous insulin administration for correction of hyperglycaemia before FDG injection, there is ongoing concern about the risk of hypoglycaemia. The Peter MacCallum group developed a weight-based intravenous insulin protocol to mitigate this risk.[22] However, their study demonstrated that hypoglycaemia still occurred, predominantly in individuals with type 1 diabetes or those with a lower body mass index. In an effort to further reduce the hypoglycaemia risk, we developed a subcutaneous insulin algorithm, using either total daily insulin dose or patient weight to estimate insulin sensitivity. In the absence of high-quality clinical trial data in this setting, this approach was formulated based on expert consensus and clinical experience.

Thus, variability in insulin sensitivity, dietary intake and concurrent comorbidities can all influence the risk of adverse outcomes, including hypoglycaemia, especially in patients with lower body weight. By outlining the appropriate management of diabetes medications and alternative management strategies, the guideline aims to mitigate these risks and improve patient outcomes. Furthermore, implementing this guideline is expected to streamline workflow efficiency within the nuclear medicine department. By reducing the likelihood of having to reschedule or repeat scans due to poorly controlled blood glucose levels, the guideline aims to optimise resource utilisation and minimise unnecessary delays.

Conclusion

This guideline offers tailored protocols based on the diabetes type and insulin requirement. For patients with type 2 diabetes not requiring insulin, the morning oral diabetic medications should be withheld if the patient fasts from midnight but can be continued if the patient is allowed to have breakfast. For those requiring insulin therapy, including patients with type 1 and type 2 diabetes, the guideline provides preparation instructions for patients either fasting from midnight or having breakfast. Patients with type 1 diabetes using multiple daily injections or insulin pumps require additional guidance on glucose monitoring and insulin pump removal. Collaboration with endocrinology specialists is advised for complex cases. Post-scan instructions stress the importance of checking blood glucose levels before departure.

This guideline aims to standardise care, streamline patient management and enhance the quality of FDG PET/CT scans for people with diabetes across Australia. This document will assist nuclear medicine centres in preparing patients with diabetes for FDG PET/CT scans with a structured, yet personalised, approach to optimise image quality and ensure patient safety.

Data availability statement

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

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