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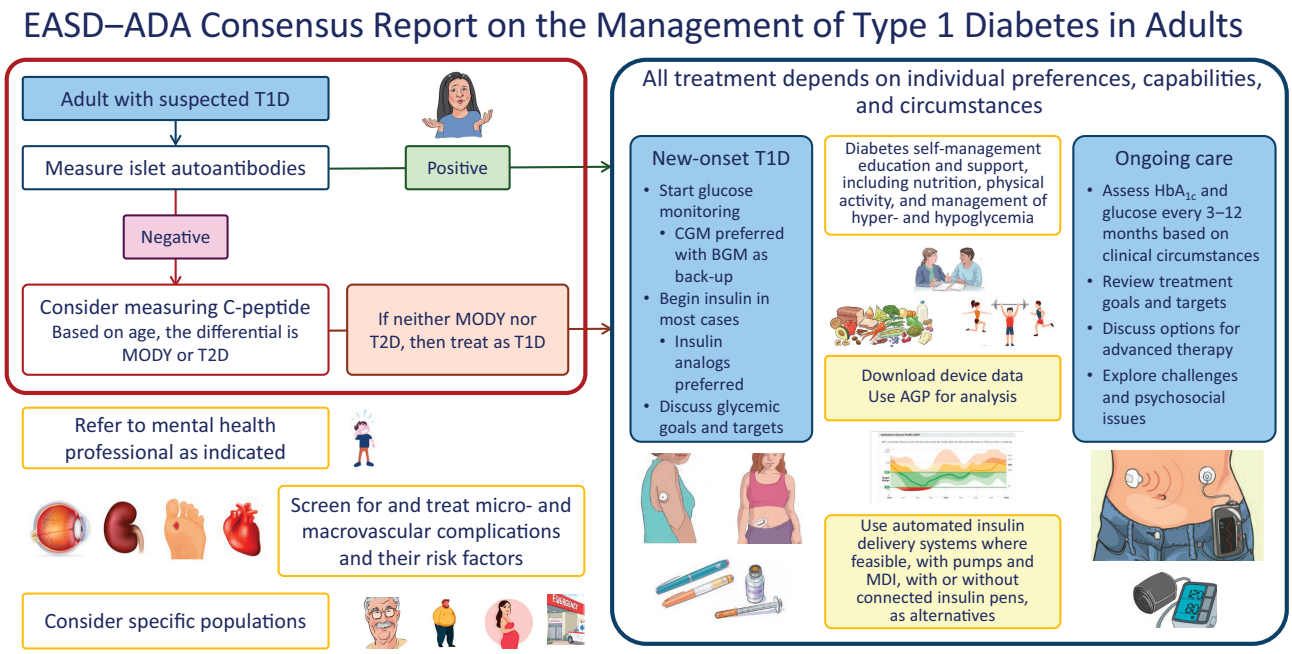


AGP, ambulatory glucose profile; BGM, blood glucose monitoring; CGM, continuous glucose monitoring; MDI, multiple daily injections; MODY, maturity-onset diabetes of the young; T1D, type 1 diabetes; T2D, type 2 diabetes. Graphical elements were adapted from the 2021 EASD/ADA consensus report (https://doi.org/10.1007/s00125-021-05568-3). Original sources could not be definitively identified.

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# The Management of Type 1 Diabetes in Adults. The Updated 2026 Consensus Report by the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD)

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**This 2026 consensus report from the European Association for the Study of Diabetes (EASD) and the American Diabetes Association (ADA) builds on the 2021 consensus report to provide guidance for managing type 1 diabetes in adults. Reflecting the rapid advances in the field, this update places particular emphasis on the integration of new technologies, while all sections have been revised to incorporate new evidence, advances in clinical practice, and novel therapies, including interventions to delay the onset of stage 3 type 1 diabetes. It also broadens its scope to screening for long-term diabetes complications, and the management of obesity and cardiovascular risk factors. Psychosocial care and diabetes self-management education and support (DSMES) remain key elements.**

The report was developed using the Accurate Consensus Reporting Document (ACCORD) framework. The guidance aligns with the current ADA "Standards of Care in Diabetes" (Standards of Care) and relevant EASD and ADA documents and aims to support clinicians globally in delivering high-quality, personalized care for adults with type 1 diabetes, with recommendations that can be adapted across diverse health care systems and resource settings.

## SECTION 1: INTRODUCTION AND RATIONALE FOR THE CONSENSUS REPORT

Type 1 diabetes is an autoimmune condition characterized by destruction of insulin-producing β-cells, resulting in profound insulin deficiency. Globally, type 1 diabetes affects an estimated 9 million people worldwide and accounts for 1–2% of all diabetes cases, while in Europe and North America it represents around 5% of diabetes diagnoses (1). Although incidence peaks in adolescence and early adulthood, it can develop at any age; in the U.S., the median age at onset is 24 years, with over half of new cases occurring in adults (2). Owing to long survival after diagnosis, the prevalence is higher among adults than children (3).

Since insulin's discovery over a century ago, advances in insulin formulations, delivery systems, and glucose monitoring technologies have transformed care. However, many individuals remain above the glycemic targets for preventing complications, contributing to the persistent physical and emotional burden of living with type 1 diabetes.

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CONSENSUS REPORT
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In response to these challenges, and the rapid pace of development, the European Association for the Study of Diabetes (EASD) and American Diabetes Association (ADA) published a consensus report in 2021 on the management of type 1 diabetes in adults focusing on glycemic management and acute complications (4,5).

This updated version addresses recent developments, including interventions to delay the onset of diabetes, emerging therapies, and new technologies. The 2021 consensus report included a detailed section on starting and adjusting subcutaneous insulin regimens (4,5). We elected not to include these details in this update, as the principles have not changed significantly and other resources are available (4–8). The current report broadens the scope to screening for long-term diabetes complications, and management of obesity and cardiovascular risk factors, while psychosocial care and diabetes self-management education and support (DSMES) remain integral components. In addition, we have added key points at the beginning of each section. Although developed by authors from Europe and the U.S., both EASD and ADA serve an international membership, and our aim is to support clinicians in optimizing care for people with type 1 diabetes, wherever they work.

This report follows the Accurate Consensus Reporting Document (ACCORD) principles (9). The 14-member writing group was appointed by the EASD Committee on Clinical Affairs on behalf of the EASD Board, and the ADA's scientific leadership on behalf of the ADA Board, based on their clinical and research expertise in type 1 diabetes. It included equal representation from both organizations across different clinical disciplines, with attention to gender and geographical balance. All members of the original writing group participated in this update, which was cochaired by Richard Holt (EASD) and Anne Peters (ADA). Two or four members of the writing group were assigned to be the primary authors of each section. These individuals had specific knowledge of the area and were tasked with reviewing and summarizing the available literature.

Before the evidence review and writing began, the writing group met twice online to agree on goals, content, methodology, and the writing teams to lead the report subsections. The section leads conducted literature searches to identify additional English-language studies published between January 2021 and July 2025. Evidence is drawn from observational and interventional studies, reflecting the limited availability of high-quality randomized controlled trials (RCTs) in many areas. Questions on clinical practice and interprofessional team collaboration for the management of type 1 diabetes provided the core of this report.

Recorded monthly virtual meetings (January 2025–August 2025) and ongoing email and web-based collaboration supported development. Meetings were held under the auspices of EASD, and a member of the ADA scientific team was present for all discussions. Writing group members collaboratively identified the topic areas and sections that needed to be updated during open discussions. Topic areas and questions were posed to the full group by the chairs and other writing group members during meetings. Discussions were carried out in detail to clarify meaning, resolve questions and bring forward new ideas. Qualitative meeting summaries were shared with writing group members and allowed reflection and opportunities to air discussion points throughout the development of the report until consensus was reached. All writing group members collectively reviewed all sections to verify scientific rigor, language, and utility to the intended readership. Each section, in turn, was revised and approved by the entire writing group.

The guidance aligns, where possible, with the current ADA Standards of Care (6,10–20) and relevant EASD and ADA guidance documents (21–25). The draft report was presented at the EASD Annual Meeting in Vienna in 2025, after which public comments were invited from health care professionals and people with lived experience of type 1 diabetes. Several revisions were made in response to this input. The revised consensus report was peer reviewed externally and by EASD and ADA, and further changes were incorporated where appropriate.

The report represents the consensus of the writing group, acknowledging limitations in the evidence base.

## SECTION 2: DIAGNOSIS OF TYPE 1 DIABETES

***Key Points***

- Adults with new-onset type 1 diabetes are frequently misdiagnosed as having type 2 diabetes, leading to delays in insulin treatment and an increased risk of diabetic
- Accurate classification of diabetes type has important clinical implications, influencing education, treatment strategy, and access to both technologies and adjunctive therapies.
- A diagnostic algorithm that integrates clinical features with islet autoantibody and C-peptide measurement can guide classification, particularly when the diagnosis is not self-evident.

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*This article underwent external peer review. Following this, the report was assessed for EASD by its Committee on Clinical Affairs and approved by its Executive Board and for ADA by its Professional Practice Committee.*

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- No single clinical feature or biomarker confirms type 1 diabetes in isolation, and diagnosis may require integration of clinical presentation with immunological and biochemical data and reassessment over time when uncertainty persists.
- Islet autoantibodies are highly sensitive markers, with approximately 90–95% of people presenting with clinical features of type 1 diabetes testing positive.
- C-peptide provides complementary information on endogenous insulin secretion and is particularly valuable when islet autoantibodies are absent or the clinical course is atypical.
- Three stages of type 1 diabetes have been defined, reflecting disease progression from islet autoimmunity with normoglycemia to dysglycemia and overt diabetes. These stages may guide screening efforts and the development of therapeutics for early intervention in the disease process.

Adults with new-onset type 1 diabetes may present after a short illness lasting 1–4 weeks or with a more slowly evolving disease course that can be mistaken for type 2 diabetes. Several other types of diabetes, for example, ketosis-prone type 2 diabetes (26), can be misdiagnosed as type 1 diabetes. In older adults, pancreatic cancer may present with diabetes and weight loss.

Most diagnostic data are derived from White European populations and may not be representative of other ethnic groups. Furthermore, most studies of the pathophysiology and natural history of type 1 diabetes come from children, and the pathogenesis of adult-onset type 1 diabetes may differ (27). The clinical presentation may vary, but the classical triad of thirst and polydipsia, polyuria, and weight loss are common symptoms of type 1 diabetes. Accurate classification of the type of diabetes has implications beyond insulin treatment. Education, insulin regimen, use of adjuvant therapies, access to newer technologies, need for psychosocial support, and concurrent disease screening may all depend on the diagnosis an individual receives. Furthermore, accurate diagnosis allows an assessment of the risk of diabetes in first-degree relatives and appropriate counseling. Although profound insulin deficiency is the hallmark of type 1 diabetes, some adults with type 1 diabetes retain some insulin secretion for years postdiagnosis and may not require insulin treatment initially (28). This can create diagnostic ambiguity about the diabetes type and its optimal management. The use of a diagnostic algorithm for the investigation of adults with suspected type 1 diabetes can help mitigate this uncertainty (Fig. 1).

### Differentiating Type 1 Diabetes From Type 2 Diabetes

Identifying type 1 diabetes in adults with newly diagnosed diabetes may be challenging, particularly when clinical features overlap with those of type 2 diabetes, such as older age with low or normal BMI or younger age with elevated BMI. Diabetic ketoacidosis (DKA), once considered pathognomonic of type 1 diabetes, may occur in ketosis-prone type 2 diabetes and in other types of diabetes, including that precipitated by use of SGLT2 inhibitors. Ketosis-prone type 2 diabetes is typically characterized by overweight or obesity, absence of islet autoantibodies, and measurable C-peptide shortly after resolution of the initial ketoacidosis (29).

Misclassification of type 1 diabetes in adults is common; over 40% of individuals diagnosed after age 30 years are initially treated as having type 2 diabetes (30–32). This misdiagnosis of type 2 diabetes is particularly likely in those with overweight or obesity and may cause confusion and distress. No single clinical feature confirms type 1 diabetes in isolation (33). The most discriminative feature is younger age at diagnosis (<35 years), with lower BMI (<25 kg/m$^2$), unintentional weight loss, DKA, and glucose >20 mmol/L (>360 mg/dL) at presentation also being informative. Other features classically associated with type 1 diabetes, such as ketosis without acidosis, osmotic symptoms, family history, or a history of autoimmune diseases, are weak discriminators (32,33).

The strong relationship between age and type 2 diabetes incidence means that even "classical" features of type 1 diabetes may have a limited predictive value in older adults, in whom type 2 diabetes is far more common (34). Most older adults with low BMI will have type 2 diabetes (33,35,36), especially in ethnic groups with a high risk of type 2 diabetes (37). Rapid progression to insulin treatment (<3 years) is highly suggestive of type 1 diabetes at any age (30,32,38).

The term "latent autoimmune diabetes in adults" (LADA) is used to describe adults with diabetes who have islet autoantibodies but do not initially require insulin therapy. However, LADA is a controversial concept with no universally accepted diagnostic criteria and considerable heterogeneity in clinical presentation and progression (39,40). Proposed definitions vary by age, autoantibody titer, and duration of insulin independence, resulting in a diverse group of individuals. Earlier studies are likely to have been confounded by including mixed populations of individuals with either type 1 diabetes or type 2 diabetes (41). LADA represents a spectrum of type 1 diabetes, rather than a distinct subtype, characterized by slower β-cell loss than in children with type 1 diabetes and variable progression to insulin dependence. Use of the LADA label may be misleading and risks delaying insulin initiation. Management should focus on autoimmune status, insulin secretion, and clinical course.

Some individuals have features of both type 1 diabetes and type 2 diabetes, for example, islet autoimmunity as well as obesity or insulin resistance, as indicated by high insulin requirements. There are no diagnostic criteria enabling a later diagnosis of type 2 diabetes in people with established type 1 diabetes. Nevertheless, recognizing a second diabetes diagnosis may be important to facilitate access to noninsulin therapies (see section 8).

### Investigation of Adults With Suspected Type 1 Diabetes

Although an initial diagnosis of type 1 diabetes is generally made on clinical grounds in adults presenting with hyperglycemia, the measurement of islet autoantibodies and C-peptide can help distinguish type 1 diabetes from other types of diabetes.

#### *Islet Autoantibodies*

Assessment of islet autoantibodies at diagnosis is recommended as the primary investigation in adults with suspected type 1 diabetes, where available. GAD antibody testing should be performed first; if negative, follow-up testing for IA-2 and/or ZNT8 antibodies should be performed, where available, as this can reduce the false-negative rate. Islet cell antibody (ICA) measurement is no longer recommended because of its imprecision and replacement by direct single antibody assays (42,43).

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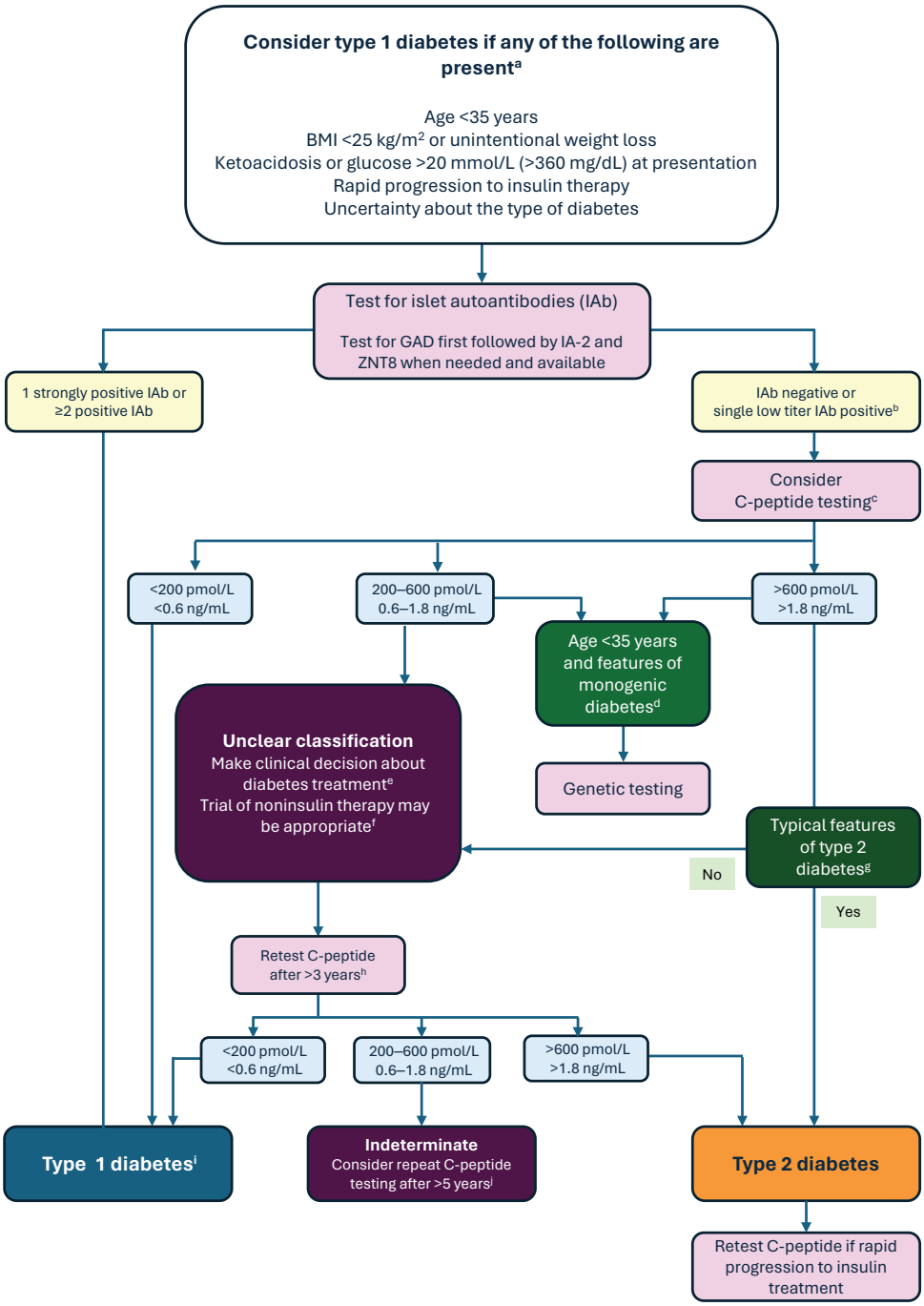


**Figure 1**—Flow chart for the investigation of suspected type 1 diabetes in adults. [a]No single clinical feature confirms type 1 diabetes in isolation. Each of the listed factors should prompt consideration of type 1 diabetes but must be interpreted alongside other clinical and biochemical findings. No single clinical feature alone should automatically trigger islet autoantibody testing. Other weaker discriminators include the presence of autoimmunity, osmotic symptoms, ketosis without acidosis, and first-degree relatives with type 1 diabetes (32,33). [b]The definition of low titer is dependent on the assay and laboratory used (43,45). Please refer to local advice. [c]A random C-peptide test should be performed with concurrent glucose measurement within 5 h of eating (28,32,53). If the result is ≥600 pmol/L (≥1.8 mg/mL), the circumstances of testing do not matter. If the result is <600 pmol/L (<1.8 mg/mL) and the concurrent glucose level is <4 mmol/L (<72 mg/dL) or the person may have been fasting, consider repeating the test (53). Tests showing very low C-peptide levels (<80 pmol/L [<0.24 mg/mL]) do not need to be repeated. In individuals treated with insulin, C-peptide must be measured prior to insulin discontinuation to exclude severe insulin deficiency. Do not test C-peptide within 2 weeks of a hyperglycemic emergency, within 12 h of a severe hypoglycemic episode, or in individuals with end-stage renal failure (due to altered clearance). [d]Monogenic diabetes should be considered when there are clinical features that are unusual in type 1 or type 2 diabetes (59). A high probability on a monogenic diabetes prediction model (www.diabetesgenes.org/exeter-diabetes-app/ModyCalculator; accessed 22 April 2026) and the presence of one or more of the following clinical features is suggestive of monogenic diabetes: $HbA_{1c}$ <58 mmol/mol (<7.5%) at diagnosis, one parent with diabetes, or features of a specific monogenic cause (e.g., renal cysts, partial lipodystrophy, maternally inherited deafness, severe insulin resistance in the absence of obesity). [e]Type 2 diabetes should be strongly considered in older individuals. In some cases, investigation for pancreatic cancer or other types of diabetes may be appropriate. [f]Individuals with suspected type 1 diabetes who are not treated with insulin will require careful monitoring and education so that insulin can be rapidly initiated in the event of glycemic deterioration. [g]Features of type 2 diabetes include increased BMI

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The sensitivity of islet autoantibodies for diagnosis of type 1 diabetes is higher in younger adults and in those with rapid progression to insulin dependence. In White European and North American cohorts, reported sensitivity is approximately 70–80% for GAD alone, 85–90% for GAD plus IA-2 and 90–95% when all three antibodies are measured (44,45). Sensitivity is greatest when antibodies are measured close to diagnosis, as antibody positivity declines with increasing duration of diabetes (46).

The specificity of islet autoantibodies increases markedly with higher titers, multiple antibodies, and clinical features consistent with insulin deficiency. Positivity for two or more islet autoantibodies is strongly predictive of rapid progression and severe insulin deficiency; such individuals should be considered to have type 1 diabetes, even if they do not require insulin at diagnosis (44,45).

Low-titer GAD antibodies are detectable in approximately 1–2% of the general adult population and may lead to false-positive results. Isolated low-titer GAD antibody positivity requires cautious interpretation, and GAD should be measured only when type 1 diabetes is clinically suspected (45).

The absence of islet autoantibodies does not exclude type 1 diabetes. Approximately 5–10% of White European individuals with new-onset type 1 diabetes test negative for islet autoantibodies (32,33,47), and further diagnostic consideration is warranted. In those below 35 years of age, type 1 diabetes remains the most likely diagnosis, particularly in the absence of clinical features of type 2 diabetes or monogenic diabetes. In those aged over 35 years, the likelihood of type 2 diabetes increases with advancing age in the absence of islet autoantibodies. However, differentiating between type 1 diabetes and type 2 diabetes based solely on age and clinical features is not always accurate, particularly in people from African, Asian, Indigenous, Hispanic, and other diverse ancestral backgrounds.

A clinical decision regarding treatment is essential. Regardless of features suggestive of type 2 diabetes or the absence of islet autoantibodies, individuals with suspected type 1 diabetes should be offered insulin treatment. However, in some individuals, when the clinical course aligns more closely with type 2 diabetes, a trial of noninsulin therapy may be appropriate. Those managed without insulin will require close monitoring and education to ensure prompt initiation of insulin if glucose levels deteriorate.

#### *C-Peptide Measurement*

Plasma C-peptide measurement assesses endogenous insulin secretion and should be considered when there is uncertainty about the type of diabetes in individuals without islet autoantibodies (48,49). It should not be measured within 2 weeks of a hyperglycemic emergency or within 12 h of a severe hypoglycemic episode. C-peptide may be falsely elevated in people with end-stage renal failure due to altered clearance. C-peptide should be measured alongside a concurrent glucose concentration within 5 h of eating. If the concurrent glucose level is <4 mmol/L (<72 mg/dL) and C-peptide level is <600 pmol/L (<1.8 mg/mL), the test should be repeated (32). At present, different commercially available C-peptide assays show significant variability, which limits the clinical utility of these defined cut-off values (50). In response, there have been calls to standardize C-peptide measurements to improve diagnostic accuracy and ensure patient safety, and a process for standardization has been established (51,52).

C-peptide levels fall progressively in people with type 1 diabetes, albeit more slowly in adults than in children, and are usually low or undetectable by 3 years after diagnosis. Consequently, the discriminative value of C-peptide for distinguishing type 1 diabetes increases with time since initial diagnosis. Beyond 3 years after diagnosis, a random C-peptide test is recommended if the diabetes type remains uncertain. Measurement of C-peptide should also be considered in those with clinically diagnosed type 1 diabetes of at least 3 years' duration, as routine C-peptide testing has led to reclassification in 11% of such individuals (53). In individuals treated with insulin, this test should be performed prior to insulin tapering or discontinuation to exclude severe insulin deficiency. A persistent nonfasting C-peptide >600 pmol/L (>1.8 mg/mL) strongly suggests type 2 diabetes, and people with C-peptide in this range are often able to transition to noninsulin therapies (54–57). By contrast, except in rare circumstances, low or absent C-peptide confirms the diagnosis of type 1 diabetes. Low C-peptide concentrations may occur in some types of secondary diabetes and very long-standing type 2 diabetes, but such cases are rarely mistaken for type 1 diabetes; however, investigation of other types of diabetes may be considered when appropriate. Conditions in which C-peptide is low, such as postpancreatectomy or immune checkpoint inhibitor–induced diabetes, require similar treatment to type 1 diabetes.

A C-peptide measurement may have clinical utility earlier than 3 years after diagnosis. However, clinicians should be aware that normal C-peptide values may be seen in people with type 1 diabetes shortly after diagnosis. This scenario is more likely in adults than children because C-peptide values are typically higher at diagnosis in adults and fall more slowly (58). Consequently, while a low C-peptide concentration confirms insulin deficiency, a normal C-peptide concentration does not exclude type 1 diabetes.

### Differentiating Type 1 Diabetes From Monogenic Diabetes

Depending on the population, monogenic diabetes accounts for up to 4% of those diagnosed with diabetes before 30 years of age. The likelihood of monogenic diabetes rises to 20% where islet autoantibodies are negative and C-peptide secretion is maintained (59). Monogenic diabetes is commonly mistaken for type 1 diabetes because of the young age at onset. Accurate diagnosis of monogenic diabetes enables tailored treatment, often allowing discontinuation of insulin, and carries important implications for screening for concurrent

($\geq$25 kg/m$^2$ [$\geq$23 kg/m$^2$ in people of South Asian ethnicity]), absence of weight loss, absence of ketoacidosis and less marked hyperglycemia. [h]Consider earlier testing if clinically indicated. C-peptide <200 pmol/L (<0.6 ng/mL) will confirm type 1 diabetes (32). [i]Some types of secondary diabetes may be associated with profound insulin deficiency, e.g., pancreatitis, and should be considered if clinical features indicate this. [j]C-peptide values 200–600 pmol/L (0.6–1.8 ng/mL) are usually consistent with type 1 diabetes but may occur in insulin-treated type 2 diabetes, particularly in people with normal or low BMI or after a long duration of illness (32). As C-peptide may decline more slowly in adults than children, C-peptide levels can remain indeterminate for longer periods of time and so retesting may be required.

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**Table 1—Stages of type 1 diabetes in people with two or more islet autoantibodies**

| Stage 1 | Stage 2 | Stage 3 |
|---|---|---|
| • No IFG, no IGT, no increase in $HbA_{1c}$ | • IFG: FPG 5.6–6.9 mmol/L (100–125 mg/dL) or<br>• IGT: 2-h PG 7.8–11.0 mmol/L (140–199 mg/dL) or<br>• $HbA_{1c}$: 39–47 mmol/mol (5.7–6.4%) or ≥10% increase in $HbA_{1c}$[a] | • Diabetes meeting standard diagnostic criteria (11) |

[a]A ≥10% increase in $HbA_{1c}$ refers to a sustained relative rise from a prior baseline measurement, confirmed on repeat testing over a period of usually 6–12 months, and interpreted in the context of other measures of dysglycemia. Small absolute changes within the range of biological or analytical variability should be interpreted with caution. FPG, fasting plasma glucose; IFG, impaired fasting glycemia; IGT, impaired glucose tolerance; PG, plasma glucose.

conditions and for genetic counseling in family members (60,61).

#### *Genetic Testing*

Molecular genetic testing for neonatal diabetes should be considered in all individuals diagnosed with diabetes under 6 months of age, regardless of current age, as over 80% will have monogenic neonatal diabetes, and the 30–50% with ATP-sensitive potassium ($K_{ATP}$) channel mutations can replace insulin with sulfonylureas (62,63).

Monogenic diabetes should be considered in those with one or more of the following features: diagnosis of diabetes before 35 years of age, $HbA_{1c}$ <58 mmol/mol (<7.5%) at diagnosis, one parent with diabetes, and features of a specific monogenic cause (e.g., renal cysts, partial lipodystrophy, maternally inherited deafness, severe insulin resistance in the absence of obesity) (64). A monogenic diabetes prediction model is available at www.diabetesgenes.org/mody-probability-calculator (accessed 5 August 2025) to help identify individuals diagnosed between 6 months and 35 years who are at increased risk of monogenic diabetes (65). For people with diabetes who are of Hispanic, African, South Asian, East Asian, or other ethnicities in which young-onset type 2 diabetes is more prevalent, the probability of monogenic diabetes is lower. Low BMI and age at diagnosis are the most important discriminators for monogenic diabetes versus type 2 diabetes in these groups (66). Those at increased risk should undergo islet autoantibody and C-peptide testing. Molecular genetic testing, which is not universally available, should be considered only if islet autoantibodies are negative and nonfasting C-peptide is >200 pmol/L (>0.6 ng/mL) (67–69).

### Stages of Type 1 Diabetes

Three stages of type 1 diabetes have been defined, characterized by the presence of multiple islet autoantibodies (which may disappear in stage 3) and differentiated by the presence of normoglycemia (stage 1), dysglycemia (stage 2), or clinical diabetes (stage 3) (Table 1) (70).

Screening programs for type 1 diabetes are being implemented, although their risks and benefits remain unclear. Potential benefits of screening and early diagnosis during stage 1 or stage 2 type 1 diabetes include a lower risk of DKA at clinical diagnosis, avoidance of hospital admission, time to develop glycemic management skills through presymptomatic education and counseling, and time to psychologically adjust leading to reductions in both parental and child stress at diagnosis (71). Potential harms of screening for type 1 diabetes include psychological impacts (including anxiety, distress, and altered illness perception), overdiagnosis and medicalization, false-positive results and diagnostic uncertainty, potential inequities in access and outcomes, and financial and resource implications.

Several recent consensus reports have addressed the early identification of type 1 diabetes and have proposed different screening and monitoring strategies, ranging from screening of first-degree relatives of people with type 1 diabetes or high genetic risk scores to population screening (21,72,73). The first two approaches lead to higher rates of positive screening but miss the majority of potential cases, as only approximately 10% of individuals with type 1 diabetes have an affected first-degree relative (74–77). Conversely, screening for antibodies among the general population yields very low positivity rates (~0.3%). Furthermore, the optimal screening time remains to be determined and the cost-effectiveness and psychosocial impact of screening need further evaluation (73). Interventions to potentially delay or prevent progression to stage 3 are being evaluated in stage 1 and stage 2 type 1 diabetes (see section 10). Individuals with stage 2 type 1 diabetes may benefit from teplizumab, an anti-CD3 antibody, which has been approved in North America, Europe, China, Asia, and parts of the Middle East and Latin America (78).

## SECTION 3: OVERVIEW OF THE MANAGEMENT OF TYPE 1 DIABETES

#### *Key Points*

- The overarching aim of diabetes care is to support people with type 1 diabetes to optimize their health and quality of life.
- Care should be person centered and tailored to the needs, priorities, and circumstances of the individual with type 1 diabetes.
- Optimizing glycemic levels remains central to preventing acute and long-term complications of type 1 diabetes but must be balanced against the risk of hypoglycemia.
- Cardiovascular risk management is an integral part of type 1 diabetes care.
- Effective management of type 1 diabetes requires ongoing education, psychosocial support, and engagement with self-management.
- Care should be delivered by appropriately trained multidisciplinary teams using flexible models of care.

Type 1 diabetes is a complex and demanding condition that requires ongoing medical, educational, and psychosocial support from health care professionals with the appropriate skills, training, and resources. Care may differ at particular times of life, such as at the point of diagnosis, during concomitant illness or pregnancy, at the onset of complications, and later in life. The aim of diabetes care and management is to support people with type 1 diabetes to live a long and healthy

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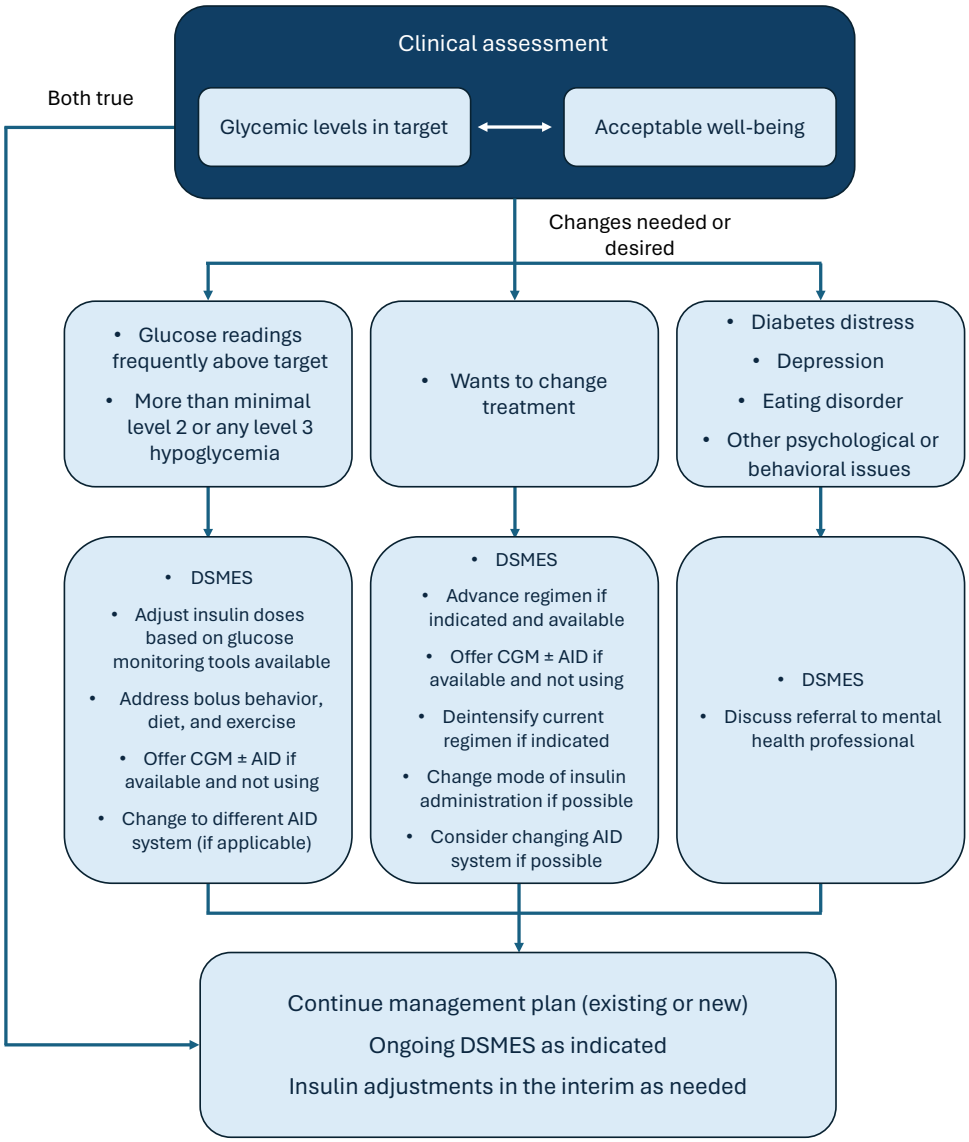


**Figure 2**—A framework for the management of individuals with type 1 diabetes, considering both glycemic levels and other psychosocial issues. AID, automated insulin delivery; CGM, continuous glucose monitoring.

life. The management strategies to achieve this aim broadly include:

- effectively delivering exogenous insulin to maintain glucose levels as close to an individual's target range as is safely possible to prevent the development and progression of diabetes complications while minimizing episodes of hypoglycemia;
- effectively managing cardiovascular risk factors;
- providing approaches, treatments, and devices that minimize the psychosocial burden of living with type 1 diabetes, while promoting engagement in self-care and psychological well-being.

The Diabetes Control and Complications Trial (DCCT) and its observational follow-up, the Epidemiology of Diabetes Interventions and Complications (EDIC) study, demonstrated the importance of glycemic management in preventing diabetes complications (79,80). Intensive insulin therapy lowered $HbA_{1c}$ by 22 mmol/mol (2%) over 7 years compared with standard care, resulting in a 60% reduction in retinopathy, 30% reduction in nephropathy, and 20% reduction in neuropathy. These benefits persisted over the long term despite the convergence of $HbA_{1c}$ levels after the trial, with reductions in cardiovascular disease (CVD) emerging over time. These landmark findings underpin current glycemic targets worldwide. $HbA_{1c}$ levels in adults with type 1 diabetes often reflect glycemic trajectories that were established earlier in life. Longitudinal cohort and registry data show that $HbA_{1c}$ typically rises during adolescence, peaks in late adolescence and young adulthood, and only partially improves thereafter (81,82). Consequently, many individuals enter adult services with elevated $HbA_{1c}$ and require additional support from their health care teams.

Although optimizing glycemic levels is critical for the prevention of acute and long-term complications, interactions with the health care team should not solely focus on glycemic management but also include consideration of well-being and treatment satisfaction. Figure 2 provides a framework for such interactions, integrating glucose-focused interventions with assessments of diabetes distress, other psychosocial issues, and satisfaction with the current treatment regimen.

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Management begins with a detailed evaluation at the initial consultation, followed by more targeted interval contacts with a focus on person-centered care (Table 2). A personalized approach to visit frequency is recommended, but visits should occur at least annually. For some people, an annual in-person consultation with the primary care team is sufficient. More frequent contact, however, may be needed for many individuals, for example, those who have been recently diagnosed, those who are not achieving their diabetes goals, those who require cardiovascular risk management, and those who would benefit from additional self-management education and psychosocial support. Additional visits may also be useful when the therapeutic regimen changes, for example, when the insulin regimen is modified or when a new device is started. Troubleshooting technology, preparation for and back-up plans in the event of system failure, and treatment of hypoglycemia should be reviewed at least annually.

Visits can be conducted in person or via telemedicine (83); however, despite the value of telemedicine, people should have the option of scheduling an in-person visit where possible (84). An annual in-person visit permits a physical examination to be undertaken, including of the feet and insulin injection or infusion sites. The use of telemedicine should be personalized and will vary depending on individual needs, computer literacy, and access to care (85). Additionally, asynchronous remote monitoring systems are being developed that can identify issues that may occur between regularly scheduled visits (86).

## SECTION 4: DIABETES SELF-MANAGEMENT EDUCATION AND SUPPORT

***Key Points***

- Diabetes self-management education and support (DSMES) is a core component of care and is recommended for all people with type 1 diabetes.
- DSMES should be offered at key time points across the life course: at diagnosis, annually or when not meeting targets, if complications develop, and when transitions occur.
- Educational content and delivery should be personalized to each individual's needs, preferences, and circumstances.
- DSMES should address both practical self-management skills and psychosocial aspects of living with type 1 diabetes.
- Structured, evidence-based DSMES programs are effective and should be delivered as an ongoing, collaborative process integrated into routine clinical care and complemented by flexible, ongoing support.

DSMES is an essential component of type 1 diabetes care that allows other diabetes interventions to work optimally. The objective of DSMES is to provide those living with type 1 diabetes (and their caregivers, if applicable) with the knowledge, skills, and confidence to successfully self-manage their diabetes on a daily basis and, thereby, reduce the risks of acute and long-term diabetes complications while maintaining quality of life (87). DSMES aims to empower people with type 1 diabetes, with an emphasis on shared decision-making and active collaboration with the health care team. Where possible, DSMES programs should be evidence based and conform to local and national standards to ensure effectiveness.

### DSMES Delivery Methods and Content

DSMES delivery methods and content should be guided by a comprehensive assessment, tailored to each individual's unique needs. This includes consideration of the time of diagnosis, prior education, psychosocial and cognitive status, literacy level, family history, and comorbidities, as well as ethnic, sociocultural, financial, geographical, and lifestyle factors (88). A structured, periodic assessment of educational needs and barriers should be an integral part of ongoing diabetes care (see Text box, "Needs assessment for DMSES"). As not all topic areas are useful or necessary for every person with diabetes every time DSMES is offered, the purpose of the assessment is to closely examine and discover current knowledge and self-management needs unbiased by the opinions of health care professionals.

DSMES can be delivered by various methods ranging from the provision of diabetes information and one-to-one advice to ongoing learning, which may be informal (e.g., through peer groups), and structured education that meets nationally agreed criteria, including evidence-based curricula, quality assurance of teaching standards, and regular audit (89). These programs are guided by learning and behavior change theories and apply effective behavior change techniques (90). While DSMES has traditionally been delivered in person, the emergence of digital platforms and creative approaches, such as online education and the use of visual storytelling through comics, has expanded the ways in which individuals with type 1 diabetes can engage with and learn about their condition (91,92).

**Needs assessment for DSMES**

Key assessment features:

- Health history
- Cognition, functional health literacy and numeracy
- Health beliefs and attitudes
- Emotional health and support systems
- Religious and cultural influences
- Physical limitations
- Social determinants of health (e.g., financial status)
- Barriers

Structured programs for adults with type 1 diabetes are effective in improving both glycemic outcomes and psychosocial outcomes (89). Structured DSMES programs most often include multiple components and cover a broad range of topics, from pathophysiology to medical technology and healthy coping (Table 3).

DSMES should not be delivered as a one-off invention but should be offered on an ongoing basis and tailored to an individual's changing educational needs. People with type 1 diabetes may be diagnosed at a young age or during adulthood, and many live with type 1 diabetes throughout different life stages. There are four key moments when DSMES is especially important: *1*) at the time of diagnosis, *2*) when glycemic targets are not being met, *3*) during periods of transition, and *4*) on the development of diabetes-related complications (Fig. 3) (93). DSMES should be revisited when a child transitions to adult diabetes services, as there may be significant knowledge gaps in someone

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**Table 2—Schedule of care**

| Component of care | Details of evaluation |
|---|---|
| Medical and family history | |
| Diabetes history | Date of diagnosis |
| | Islet autoantibodies (date measured) |
| | C-peptide with concurrent glucose measurement (date measured) |
| | Episodes of DKA |
| | Episodes of level 3 hypoglycemia |
| | Hypoglycemia awareness |
| Family history | Type 1 diabetes or type 2 diabetes in first-degree relatives |
| | Other autoimmune disorders |
| Common comorbidities | Autoimmune disorders: thyroid, celiac, other[a] |
| | Hypertension |
| | Dyslipidemia |
| | Overweight and obesity |
| | Eating disorders |
| | Mild cognitive impairment and dementia |
| | Hearing loss |
| | Sleep disorder |
| | Dermopathy |
| | Fractures |
| | Joint and soft tissue disorders: cheiroarthropathy, trigger finger, capsulitis, carpal tunnel syndrome |
| | Dental and periodontal disease, which may contribute to altered taste |
| Other | Pregnancy and contraception history |
| | Vaccination history if applicable |
| Additional behavioral/lifestyle factors | Diet and nutrition: use of carbohydrate counting, weight history |
| | Physical activity |
| | Smoking, alcohol consumption, and substance use |
| | Sleep |
| | Occupation |
| Diabetes management | |
| Glycemic targets | $HbA_{1c}$ |
| | CGM metrics including time in range, time above range, time below range, glycemic variability, median glucose, and adequate data capture |
| Current insulin regimen | MDI: pens, including connected pens; syringes; needles |
| | Insulin pump or AID system (type/model, settings, backup injection plan) |
| Glucose monitoring | CGM: type/model, data sharing (if applicable) |
| | Capillary glucose monitoring: type of meter/strips, frequency of use, mean (SD), range, and patterns |
| Other | Noninsulin diabetes medications |
| | Glucagon prescribed when indicated (remind person with diabetes to check expiration date) |
| | Ketone testing supplies prescribed when indicated |
| | Use of diabetes software or mobile applications |
| Psychosocial issues | Monitor psychological well-being including diabetes distress, depressive symptoms, and anxiety |
| | Consider fear of hypoglycemia and disordered eating |
| | Consider the impact of social determinants of health, including finance, and arrange social support as appropriate and available |
| | Assess cognitive status |
| DSMES | Assess individual needs and plan appropriate DSMES |
| | Dietary review |
| | Consider contraception and pregnancy planning in women of child-bearing age |
| Physical examination and complications screening | |
| General | Height |
| | Weight, BMI: every visit if not stable, otherwise annually |
| | Skin, including injection/infusion sites: every visit if skin complaints or erratic glucose readings are present, otherwise annually |
| Retinopathy | Initial examination within 5 years after diagnosis, followed by examinations every 1–4 years depending on prior findings, glycemic levels, blood pressure, and comorbidities |
| | Performed using validated approaches, most commonly retinal photography |

*Continued on p. 10*

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**Table 2—Continued**

| Component of care | Details of evaluation |
|---|---|
| Nephropathy | Initial examination within 5 years of diagnosis, followed by examination every 1–2 years<br>Urinary albumin/creatinine ratio (uACR) measured in a random spot urine sample (annually) with confirmatory testing if elevated (repeat spot urine or 24 h collection)<br>Creatinine and eGFR measured annually; may be more often if kidney disease present |
| Peripheral neuropathy | Initial examination within 5 years of diagnosis followed by annual examination<br>Initial assessment with 10-g monofilament<br>Further assessment may include either temperature or pinprick sensation (small-fiber function) and vibration sensation using a 128-Hz tuning fork (large-fiber function)<br>If neuropathy is present, assess TSH and vitamin $B_{12}$. Consider alternative causes where clinically indicated<br>Foot ulceration or deformity |
| Autonomic neuropathy | Screening is initially based on history and physical examination<br>History-taking should assess for symptoms such as orthostatic hypotension, syncope, early satiety, erectile dysfunction, altered sweating patterns (particularly gustatory sweating), and dry, cracked skin on the extremities<br>On examination, resting or fixed tachycardia (after ruling out hyperthyroidism), orthostatic hypotension, or evidence of peripheral dryness or cracking of the skin may be present<br>More detailed tests include heart rate variability on electrocardiography, heart rate and blood pressure response to standing, and heart rate response to a Valsalva maneuver |
| Macrovascular disease | Annual assessment but more often if abnormalities or symptoms are present. Includes blood pressure and pulse, cardiovascular examination, and assessment of lower limb pulses<br>Measurement of lipid profile: frequency dependent on the presence of previous lipid abnormalities or treatment |
| Laboratory testing | $HbA_{1c}$ every 3–12 months<br>ALT and AST: at least once and thereafter as indicated clinically<br>Serum potassium: if taking ACE-I, ARB, or diuretics<br>TSH, celiac screen: at least once and as indicated clinically[a] |
| Goal setting | Personalized, attainable, realistic: behavioral considerations (diet and nutrition, activity, smoking cessation)<br>Glycemic: $HbA_{1c}$, time in range, hypoglycemia |
| Treatment plan | Formulate treatment plan with shared decision-making |
| Referrals | As needed: podiatry, cardiology, nephrology, ophthalmology, vascular surgery, gynecology, urology, orthopedic surgery, mental health professional, dentist, others |

[a]Individuals with type 1 diabetes are at increased risk of other autoimmune diseases, including autoimmune thyroid disorders, pernicious anemia, celiac disease, collagen vascular diseases, and Addison disease (382). The optimal frequency of screening for these conditions in adults has not been established. Where indicated in the table, screening frequencies are in line with the ADA Standards of Care (6,10,12–17,19). ACE-I, ACE inhibitor; AID, automated insulin device; ALT, alanine aminotransferase; ARB, angiotensin II receptor blocker; AST, aspartate aminotransferase; CGM, continuous glucose monitoring; MDI, multiple daily injections; TSH, thyroid stimulating hormone.

diagnosed early in life, when education is directed at parents and caregivers. DSMES should also be revisited when there is a transfer of health care services or when a caregiver takes over any aspect of diabetes management to identify any new educational requirements.

An emerging area is the increase in number of individuals diagnosed with pre–stage 3 type 1 diabetes, as a result of type 1 diabetes screening efforts, and DSMES is needed for this group of people and their families (21). DSMES should be provided based on current needs and include the practical and psychosocial implications of their antibody status, the benefits of regular monitoring, and symptom awareness.

A wide range of smartphone and web-based applications (apps) are available to support people with type 1 diabetes in managing the complexities of daily self-care. While these tools are increasingly popular, the evidence supporting their safety, accuracy, and clinical effectiveness remains limited. Key concerns include insufficient validation of app algorithms, lack of standardized training for users, poor interoperability with other devices and systems, and inadequate data privacy protections (25).

Effective use of diabetes health apps requires ongoing dialogue between the health care team and the individual with diabetes (94). This includes assessing the person's understanding of the app's content, their digital literacy, and the influence of social determinants of health on their ability to engage with the technology. It is equally important that health care professionals maintain up-to-date knowledge and competency regarding the apps their patients use. This enables informed evaluation of whether a given app is appropriate, safe, and beneficial for an individual's care needs.

## SECTION 5: HEALTH-RELATED BEHAVIORS

Health-related behaviors, such as eating patterns, physical activity, sleep, and stress management, play a critical role in optimizing glycemic levels, reducing

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**Table 3—Key content areas of DSMES**

| Content area | Examples that focus on type 1 diabetes |
|---|---|
| Diabetes pathophysiology and treatment options | Immunology of β-cell destruction |
| Healthy eating | Basic and advanced carbohydrate counting vs. intuitive dosing<br>Impact of meal composition (fat, protein, glycemic index, fiber, sugar, alcohol) on glucose levels<br>Use of technology to enhance dosing recommendations |
| Physical activity | Impact on glucose and insulin dose recommendations |
| Medication usage | Types of insulin<br>Methods of insulin delivery |
| Monitoring and using patient-generated health data | Technology and its ability to provide more frequent remote communication between people with type 1 diabetes and their health care professionals<br>Review of CGM, pump, and connected insulin pen downloads and applications |
| Acute complications (hypoglycemia, hyperglycemia, and DKA), sick-day advice, and preparedness for emergencies | Signs and symptoms of DKA, including euglycemic DKA<br>Problem solving insulin pump issues or malfunctions, including unexplained hyperglycemia, setting requirements, and infusion set and site issues, such as occlusions<br>Back-up plan for pump/CGM failure (e.g., availability of insulin for injection and doses, meter and test strips)<br>Glucagon use<br>Ketone testing |
| Preventing, detecting, and treating chronic complications, including immunizations and preventive eye, foot, dental, and renal examinations, as indicated by an individual's duration of diabetes and health status | Understanding individual risk for complications in type 1 diabetes<br>Preventing the development and progression of complications in the future |
| Healthy coping with psychosocial issues and concerns | Discussing strategies to help reduce diabetes distress and prevent "diabetes burnout" |
| Problem solving | Goal setting<br>Developing personal strategies to promote health and behavior change<br>Identifying problems and solutions<br>Identifying and accessing resources<br>Sick-day advice<br>Management of pump failure or pump holidays<br>Planning for procedures or surgery<br>Preconception planning<br>Pregnancy and diabetes |

CGM, continuous glucose monitoring; DKA, diabetic ketoacidosis; MDI, multiple daily injection.

the risk of complications and enhancing overall quality of life (95). These behaviors often cluster, such that individuals may simultaneously engage in multiple healthy or unhealthy habits, which can amplify their impact on health outcomes. Religious and other cultural considerations, such as fasting, may also impact self-management of type 1 diabetes, and health care professionals should provide appropriate guidance and support to accommodate this (96). Health care professionals should adopt an integrated, person-centered approach to type 1 diabetes care that considers individual behavioral profiles and tailors interventions accordingly.

## Nutrition Therapy

***Key Points***

- Nutrition therapy is personalized and aligned with an individual's preferences, culture, health literacy, and access to food.
- Carbohydrate intake is the primary dietary determinant of postprandial glucose and should guide prandial insulin dosing.
- Carbohydrate counting is effective, but alternative strategies (e.g., consistency or intuitive dosing) may be appropriate.
- Meal composition (fat, protein, fiber, alcohol) influences glycemic responses and insulin needs.
- Low-carbohydrate and very-low-carbohydrate eating patterns may be used safely with appropriate education and monitoring.

Nutrition, in particular carbohydrate intake, has a major effect on blood glucose levels, and people with type 1 diabetes need to understand the effect of food on their diabetes and plan meals accordingly (see Text box, "Goal of nutrition therapy for type 1 diabetes"). People with type 1 diabetes should be referred for personalized medical nutrition therapy provided by a registered dietitian who is knowledgeable and skilled in providing diabetes-specific

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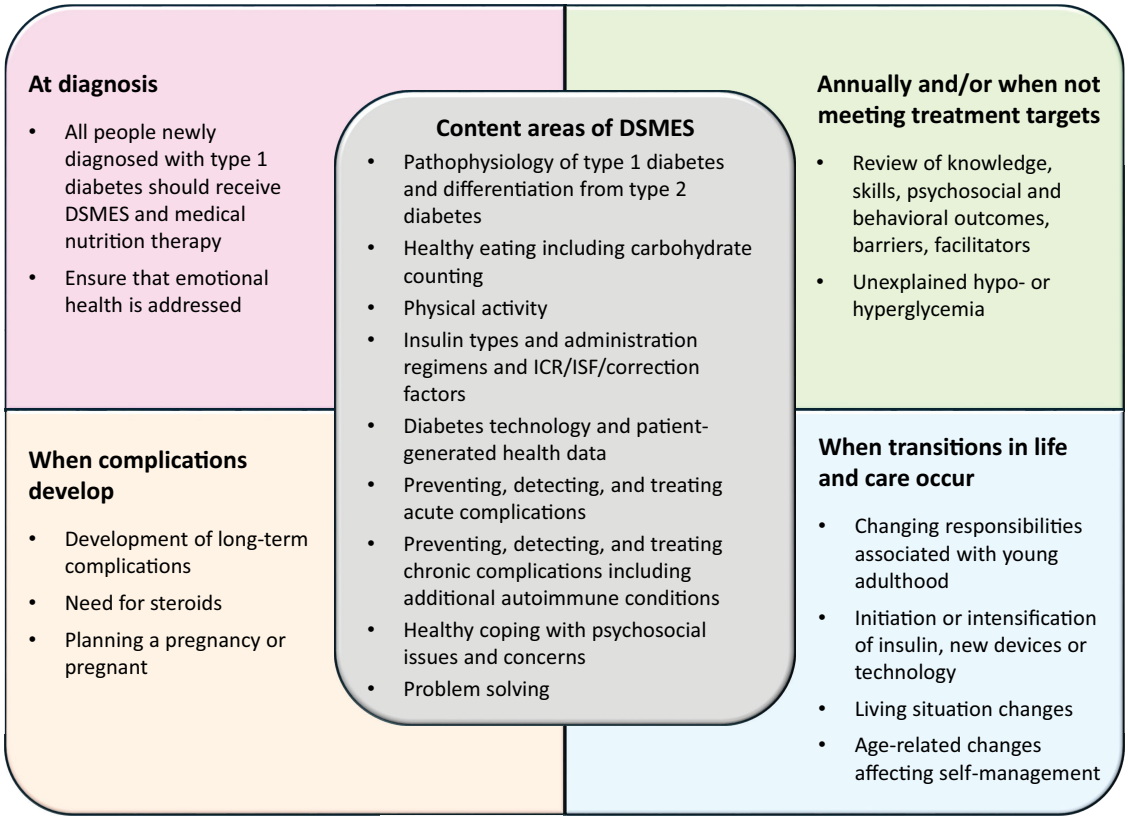


**Figure 3**—The four critical times when DSMES is particularly needed for people with diabetes (and their caregivers, when applicable). ICR, insulin/carbohydrate ratio; ISF, insulin sensitivity factor.

nutritional advice in conjunction with the diabetes technology being used. When integrated into an overall management program, medical nutrition therapy delivered by a registered dietitian is associated with a reduction in $HbA_{1c}$ of 11–21 mmol/mol (1.0–1.9%) in people with suboptimally managed type 1 diabetes (12).

Nutritional recommendations for people with type 1 diabetes are based on personal preferences, socioeconomic status, cultural background, and comorbidities. Carbohydrate counting is the most common meal planning approach in type 1 diabetes. In conjunction with promoting healthy eating patterns, carbohydrate counting and the use of insulin/carbohydrate ratios can be useful methods for adjusting mealtime insulin dosing for optimal glycemic outcomes (97). When carbohydrate counting is not possible, teaching carbohydrate consistency is an alternative approach. While low-carbohydrate and very-low-carbohydrate eating patterns are increasingly popular, reduce $HbA_{1c}$ levels, and increase time in range in the short term, it is important to incorporate these alongside healthy eating guidelines.

## Goal of nutrition therapy for type 1 diabetes (12)

- Promote healthy eating patterns, emphasizing a variety of nutrient-dense foods in appropriate amounts to improve overall health, $HbA_{1c}$, blood pressure, and cholesterol and aid maintenance of weight or achievement of weight goal
- Personalize nutrition advice based on individual and cultural preferences, health literacy, and access to healthy food choices
- Provide practical tools for day-to-day meal planning
- Focus on helping people dose their prandial insulin based on their ability to master carbohydrate-counting skills

Additional meal components, including high fat and/or high protein, may contribute to delayed hyperglycemia and the need for insulin dose adjustments. As the glycemic impact of a mixed meal varies substantially between individuals, and between people using multiple daily injections (MDI) and those using automated insulin delivery (AID) systems, postprandial glucose monitoring for up to 3 h or longer may be needed to determine initial and subsequent correction doses (12).

New interactive technologies using mobile phones to provide information, insulin bolus calculations based on insulin/carbohydrate ratios, and telemedicine communications with care providers may aid in reducing both weight gain and the time required for education (25). Artificial intelligence (AI) is increasingly being used to evaluate meal composition and is being integrated into various devices.

In the case of extreme low weight, unhealthy eating habits should be reviewed, including the possibility of insulin omission. Disordered eating is discussed further in section 6.

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### Physical Activity

***Key Points***

- Regular physical activity, including sports, should be encouraged for most people with type 1 diabetes, given its cardiovascular, metabolic, and psychosocial benefits.
- Different types, intensities, and durations of activity have variable effects on glucose levels and insulin requirements.
- Education should focus on balancing insulin dosing, carbohydrate intake, and glucose monitoring to reduce hypoglycemia and hyperglycemia.
- Diabetes-related technologies, such as AID systems, may support safe participation in physical activity when adjusted appropriately.
- Individual contraindications and diabetes complications should be considered when advising on activity type and intensity.

A combination of aerobic and resistance exercise on most days is associated with improved fitness, increased insulin sensitivity leading to reduced insulin requirements, improved cardiovascular health with better lipid profiles and endothelial function, and decreased mortality risk (98–100). Although regular exercise confers glycemic benefits, including improvement in $HbA_{1c}$, evidence for an independent beneficial effect on the preservation of β-cell function in early type 1 diabetes remains limited and inconclusive (101,102). Regular physical activity is also associated with reduced risks of microvascular complications and osteoporosis (100,103). Exercise helps maintain a healthy BMI and promotes sleep quality and psychological well-being.

Although most people with type 1 diabetes should be encouraged to undertake physical activity safely, it is important to consider cardiovascular and lower extremity comorbid conditions. Advice should be given regarding appropriate footwear and foot inspection for those with peripheral neuropathy to avoid the risk of ulceration. Walking does not increase the risk of ulceration in people with peripheral neuropathy, but weight-bearing exercise should be avoided in active foot disease (104). In individuals with proliferative or severe nonproliferative diabetic retinopathy, vigorous aerobic or resistance exercise involving straining should be avoided because of the risk of vitreous hemorrhage or retinal detachment (105). These individuals should consult an ophthalmologist before beginning any high-intensity exercise program.

Education regarding physical activity should focus on the acute effects of exercise on glucose concentrations, which depend on several factors, including the individual's baseline fitness level; the type, intensity, and duration of activity; the amount of insulin in the circulation; the blood glucose concentration before exercise; and the composition of the last meal or snack. People with type 1 diabetes should learn about the effects of exercise on glucose levels and how to balance exogenous insulin delivery and carbohydrate intake for different types and intensities of exercise to minimize the risks of hypoglycemia and hyperglycemia (see Text box, "Considerations for glycemic management during exercise"). Post-exercise hypoglycemia can occur up to 24 h after the end of physical activity, and its occurrence is higher in untrained individuals and those engaging in physical activity irregularly (106). While general recommendations can be made (see Supplementary Material 1), the glycemic effects of physical activity and exercise can differ within and between individuals, highlighting the importance of experiential learning. Nevertheless, diabetes health care professionals can guide and support individuals with type 1 diabetes to reduce anxiety and build confidence around physical activity.

The introduction of continuous glucose monitoring (CGM) and AID systems has enabled more nuanced and proactive strategies to support safe participation in physical activity, including approaches to minimize hypoglycemia and hyperglycemia during and after exercise (107). Detailed guidance is beyond the scope of this report but the consensus statement for management of exercise in type 1 diabetes provides detailed suggestions regarding the use of CGM trend arrows and adjustment of insulin doses and carbohydrate intake (105). EASD and ISPAD have also developed a position statement on the use of AID systems during exercise (24).

#### Considerations for glycemic management during exercise

- Type, duration, and intensity of exercise
- Time of day
- Fasting or nonfasting
- Acute and delayed effects of exercise on glucose concentrations
- Previous episodes of hypoglycemia
- Glucose monitoring before, during, and after physical activity
- Insulin dose adjustments up to 2–3 h before and after physical activity
- Insulin on board
- Management of hypoglycemia and hyperglycemia during and after physical activity
- Safety measures such as use of medical ID, availability of carbohydrates to consume before, during, and after exercise, exercising with others, glucagon, adequate hydration, back-up supplies in case AID/CGM fails for longer duration or more remote exercise

Further details are provided in Supplementary Material 1.

### Sleep

***Key Points***

- Many people with type 1 diabetes have disrupted sleep that may directly and indirectly adversely affect glucose levels.
- Health care professionals should ask about and support the management of diabetes-related factors that may impact sleep or sleep disorders.

Sleep patterns may be disrupted in people with type 1 diabetes as a result of both behavioral and physiological aspects of diabetes and its management, including, but not limited to, technology alerts and fear of overnight hypoglycemia (108–110). Many individuals with type 1 diabetes sleep less than current recommendations and have an increased risk of sleep-disordered breathing, which is associated with an increased risk of long-term diabetes complications (109–111).

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There are mixed reports about the effect of sleep duration on glycemic management (109–111). Reviewing the frequency and appropriateness of technology alerts and alarms is an important first step in reducing unnecessary sleep disruption. It is also essential to address the fear of nocturnal hypoglycemia and to identify strategies to minimize its risk.

### Alcohol and Recreational Drug Use

***Key Points***

- The use of alcohol and recreational drugs should be discussed to assess the potential risks and impact on glucose levels and diabetes self-management.
- Clinicians should be alert to features suggestive of substance use and ensure appropriate assessment and referral, given its association with increased risks of acute diabetes complications.

Many individuals with type 1 diabetes consume alcohol, although its effects on glycemic management are not always adequately considered. Increased alcohol consumption is associated with a higher risk of glycemic variability, typically with hyperglycemia initially and the potential for hypoglycemia hours later (112). Factors in alcoholic beverages that impact glucose levels include the amount of carbohydrate and glucose, the amount of alcohol by volume, and the volume of beverage consumed in conjunction with food. Excessive alcohol consumption impairs cognitive function and symptom awareness, leading to a diminished ability to self-manage diabetes (112). Alcohol consumption also appears to increase the risks of DKA and lactic acidosis, particularly in those with suboptimal glycemic management and in the context of reduced endogenous insulin. Alcohol inhibits hepatic gluconeogenesis, leading to an increased risk of hypoglycemia for up to 24 h after the last drink (112). Hypoglycemia is particularly hazardous because of the potential to confuse hypoglycemic symptoms with alcohol intoxication (112). Some of this glycemic variability may occur through the association with other risk-taking behaviors.

An association between recent recreational cannabis consumption and a more than twofold increased risk of DKA has been reported from countries where cannabis has been legalized, possibly related to the emergence of higher potency formulations of cannabis and other synthetic cannabinoids (113,114). Heavy users can develop cannabis hyperemesis syndrome, which mimics gastroparesis (115). Use of cocaine and other stimulant-like drugs increases glucose production and inhibits glucose clearance, which increases DKA risk. A diagnosis of a substance use disorder is associated with an increase in all-cause mortality in populations with diabetes across a range of substances, including cocaine, opioids, and cannabis (114).

Health care professionals should ask about substance use and inform people with type 1 diabetes about the effects of drugs and alcohol on diabetes and related risks to avoid them seeking information elsewhere that may be incorrect and misleading (116).

Discussions regarding the impact of substance use on self-management should also be included in the education provided. Brief interventions to reduce substance use have been well validated in various populations and have the potential to improve diabetes medication taking and outcomes (117). However, targeted research specifically in people with type 1 diabetes remains limited, and more tailored interventions are needed. In the case of substance use disorder, referral to a specialized clinic is warranted.

### Smoking

***Key Points***

- Smoking status should be assessed during routine consultations.
- Smoking cessation should be promoted and supported in all individuals with type 1 diabetes.

Smoking is a risk factor for both macrovascular and microvascular complications in individuals with type 1 diabetes (118–120). People who smoke tend to have suboptimal glycemic management, with reduced time in range, increased time in hyperglycemia, greater glucose variability, and a higher incidence of morning hypoglycemia (121). These findings emphasize the importance of smoking cessation as a crucial component of diabetes management.

### Travel and Driving

***Key Points***

- Planning ahead is the key to safe travel for individuals with type 1 diabetes.
- Safe driving practices should be discussed regularly with people who drive.

## Travel considerations for people with type 1 diabetes

- **Preparation:** Always carry diabetes-related and emergency supplies. Carry tools to keep insulin at the correct temperature
- **Insulin adjustment:** Plan insulin dosing to minimize glucose fluctuations, especially when crossing time zones. This should be supported by frequent glucose monitoring
- **Environmental factors:** Be mindful of changes in routine, climate, stress levels and physical activity that can affect glucose levels
- **Diet:** Research local foods to estimate carbohydrate content for better insulin management
- **Communication:** Carry note cards in the local language indicating that the individual has type 1 diabetes and may need urgent help in case of hypoglycemia. Smart phone apps can provide useful translation tools
- **Air travel:** Carry all supplies in carry-on/hand luggage. Consider bringing extra supplies. Declare medical equipment to security staff. Review pump and CGM manufacturer advice regarding flying. Check with national aviation security authorities regarding security screening rules

Individuals with type 1 diabetes should ensure they are well-prepared for travel and that all necessary diabetes-related and emergency supplies are easily accessible while traveling (see Text box, “Travel considerations for people with type 1 diabetes”) (122).

Unrecognized hypoglycemia and rapidly dropping glucose levels are the most relevant hazards for drivers with type 1 diabetes (123). These risks may be reduced by monitoring glucose prior to driving and at regular intervals during longer drives.

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Local regulations and recommendations for driving with type 1 diabetes should be followed.

### Employment

***Key Points***

- People with type 1 diabetes should have equal opportunities to pursue a wide range of careers.
- Employers should provide reasonable accommodation in accordance with local and national guidelines to enable people with type 1 diabetes to perform their roles effectively.
- Where the essential requirements of a role cannot be met without unacceptable risk to the person with diabetes or others around them, alternative roles may need to be considered.

People with type 1 diabetes are able to successfully undertake many different jobs; however, stigma and misconceptions about diabetes, particularly concerns about hypoglycemia and insulin access in challenging environments, can still limit employment opportunities (124). Chronic complications may also affect suitability for certain roles. While some occupations continue to restrict individuals with diabetes because of perceived safety risks, progress has been made in broadening employment opportunities, including to professions such as commercial airline pilot. It is not always necessary to disclose having type 1 diabetes, but some workplaces have specific protocols for safe employment for those with type 1 diabetes. People should coordinate with their human resources department if there are any issues. An updated ADA statement provides guidance for workers with diabetes, their health care teams, and employers navigating the legal and practical considerations for diabetes in the employment setting, including reasonable accommodations and the legally required interactive process between employers and workers (125).

To support safe and equitable employment, individuals with type 1 diabetes should be encouraged to pursue any role they are qualified for and can perform safely. Workplaces should provide reasonable accommodations, if possible, including access to insulin and glucose monitoring and time for self-management of blood glucose levels. Employment laws differ between countries and sometimes between different regions within a country.

## SECTION 6: PSYCHOSOCIAL CARE

***Key Points***

- Psychosocial factors should always be considered as part of routine adult diabetes care, which should be nonjudgmental, person centered, and responsive to changing life circumstances.
- Periodic screening of psychological well-being is recommended, at least annually, using validated questionnaires.
- Psychosocial problems are associated with increased risks of suboptimal self-management, higher $HbA_{1c}$, and diabetes-related complications.
- The diabetes team should preferably include a mental health professional who can advise the team and consult with people with diabetes in need of psychological support.

Type 1 diabetes is a psychologically challenging, chronic condition that impacts all domains of life, with treatment outcomes highly dependent on an individual's ongoing self-management. In this context, psychosocial factors play a significant role and encompass a person's cognitive functioning, beliefs, motivations, attitudes, coping strategies, feelings, and relationships with others (126). Poor mental health in type 1 diabetes is prevalent and associated with suboptimal glycemic levels and increased risks of complications (127). It is therefore imperative to adopt a biopsychosocial approach to type 1 diabetes, to achieve optimal outcomes in terms of both metabolic outcomes and psychosocial outcomes.

### Social Determinants of Health

Life circumstances can significantly impact health in people with type 1 diabetes. In a review of social determinants of health and diabetes, the following domains were found to affect people with type 1 diabetes: *1*) the neighborhood and physical environment (e.g., housing stability and interpersonal safety); *2*) the built environment (e.g., walkability, access to green spaces, and access to transportation); *3*) environmental exposures (e.g., pollution); *4*) food access, availability, and affordability; and *5*) health care access, affordability, and quality (128). Socioeconomic challenges, particularly the inability to pay for food, insulin, other medications and supplies, and utilities, should be recognized and, where possible, addressed.

### Psychological Problems

As in the general population, people living with type 1 diabetes experience chronic stress, such as stress related to work or financial hardship, as well as major stressful life events, such as unemployment or bereavement. Although not diabetes related, it is important to consider stress in type 1 diabetes because of its impact on quality of life and overall well-being and because it may also complicate diabetes self-management, thereby increasing the risk of not reaching glycemic targets (129).

Diabetes distress is common, affecting 20–40% of adults with type 1 diabetes, and can be experienced at any point from early adulthood to older age (130). "Critical" times are those following diagnosis, when complications develop, and when there is a loss of social support, for example, when an older adult loses their spouse or carer (131). Feeling powerless and overwhelmed by the daily self-care demands, fear of hypoglycemia, and worries about complications are among the most cited sources of distress by people with type 1 diabetes (132). Stigma, lack of social support, or feeling "policed" by family, friends, or coworkers can also evoke emotional distress in individuals with type 1 diabetes (133). Prolonged elevated diabetes distress can lead to "diabetes burnout" and is associated with an increased risk of depression, less engagement in self-care, and higher $HbA_{1c}$ levels (134).

Depression and anxiety symptoms are twice as prevalent among adults with type 1 diabetes compared with adults without diabetes and negatively impact daily functioning and quality of life (135,136). Anxiety and depression often coexist and may partly overlap with symptoms of diabetes distress (137). Depression, at all levels of severity, is a risk factor for suboptimal self-care, hyperglycemia, long-term complications, and excess mortality (138). The association between generalized anxiety disorder and suboptimal blood glucose levels is less clear (139). Fear of hypoglycemia affects up to 10% of adults with type 1 diabetes, particularly among those experiencing

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repeated episodes of level 3 hypoglycemia (140). Fear of hypoglycemia may translate into "phobic" avoidance behaviors aimed at keeping blood glucose at a "safe" level, resulting in persistent hyperglycemia. Although less common, lack of fear of hypoglycemia and/or fear of hyperglycemia may also be problematic, particularly in those with impaired hypoglycemia awareness and frequent severe hypoglycemic events (141,142).

Dysfunctional eating behaviors and eating disorders, including anorexia nervosa, bulimia nervosa, and binge eating, are overrepresented in people with type 1 diabetes, particularly in young women, but may also occur in men (143). However, people with type 1 diabetes are less likely to receive outpatient treatment for their eating disorders than their diabetes-free peers, despite their greater risk for major adverse health outcomes (144). Insulin omission may be used as a weight-loss strategy, particularly in girls and younger women, resulting in elevated $HbA_{1c}$ levels (145).

Intellectual disabilities and neurodiversity warrant attention, as they may limit a person's capacity to self-manage diabetes. Type 1 diabetes has been linked with attention deficit hyperactivity disorder (ADHD) and autism (146), with a Swedish nationwide cohort study reporting that comorbid neurodevelopmental disorders, primarily ADHD and intellectual disability, are associated with suboptimal glycemic levels and a higher risk of diabetes-related complications in childhood-onset type 1 diabetes (147).

As the life expectancy of people with type 1 diabetes increases, normal cognitive decline associated with aging may impact mental health and the capacity to self-manage diabetes and treatment outcomes. Importantly, in the 32-year follow-up of the DCCT/EDIC study, cognitive decline accelerated exponentially in participants with type 1 diabetes after 18 years of follow-up, and clinically significant cognitive impairment was found in up to 50% of older individuals with type 1 diabetes (148).

### Psychosocial Screening and Monitoring

Monitoring of well-being and quality of life issues using person-reported outcome measures should always be considered in routine consultations and should not be restricted to those who report having psychological difficulties (149,150). Assessment and periodic monitoring of an individual's mental and social health status, at least on an annual basis, is recommended to identify individual needs and promote psychological well-being, engagement in self-management, and satisfaction with care (151,152). Given the prevalence of psychological issues in type 1 diabetes, screening can assist in case finding and timely referral for those in need of additional care, not least because psychological comorbidities can negatively affect diabetes outcomes and vice versa (153).

Implementing a standardized psychosocial evaluation is feasible but may require changes to current service provision, for example inviting people with diabetes to complete a set of questionnaires online or at the clinic prior to their visit (154). Practical, validated psychosocial screening tools are available for use in type 1 diabetes care, in multiple languages (see Supplementary Material 2).

There is no universally agreed core set of psychosocial measures for use across countries as part of clinical care for adults with type 1 diabetes, but there is consensus that well-being, diabetes distress (including worries around hypoglycemia, complications, and treatment burden), depressive symptoms, and social stress are among the most important domains to assess (150,155,156).

When disordered eating behaviors are reported, referral to a specialist mental health professional for a diagnostic interview for eating disorders should be considered (157). In case of suspected cognitive impairment, brief cognitive screening is recommended, followed by referral for more elaborate cognitive testing if needed.

Clinicians conducting psychosocial screening should possess a solid understanding of the psychosocial challenges commonly faced by individuals with type 1 diabetes, particularly those that may complicate diabetes management. They should also demonstrate strong communication skills, including active listening, a nonjudgmental approach to discussing sensitive issues, and the ability to constructively explore the option of referral to in-house or external specialized psychosocial services when appropriate.

### Psychosocial Interventions

People living with type 1 diabetes may, at various stages, experience adjustment problems and diabetes distress, which should be recognized as a normal response rather than a clinical condition (158). However, this does not imply that diabetes distress should be ignored. All members of the diabetes care team have a shared responsibility to provide supportive care as an integral component of diabetes management, helping people cope with the ongoing demands of the condition. Ideally, the diabetes care team should include a mental health professional (psychiatrist, clinical psychologist, and/or social worker) with diabetes expertise, who can offer guidance to the team and direct support to those requiring psychosocial care (159,160). Social needs may be addressed by social workers and community organizations. Social support from family and friends, peer-led initiatives, and digital self-help programs can play a valuable role in helping individuals cope effectively with the psychosocial demands of living with type 1 diabetes (161,162).

Psychological therapies, including time-limited in-person or online cognitive behavioral therapy, mindfulness, acceptance and commitment therapy and interpersonal therapies, are effective with regard to self-management and a range of psychological issues, including diabetes distress and depression (163–165). The effects of individual and group psychotherapy on glycemic levels are generally small but increase when DSMES is incorporated into the treatment (166). A small proportion of adults with type 1 diabetes have psychiatric conditions requiring treatment with psychotropic medications, which may impact glycemic management. In these cases close collaboration with a specialist mental health professional is warranted (167,168).

## SECTION 7: INTERVENTIONS TO MANAGE GLUCOSE LEVELS

***Key Points***

- Lifelong insulin therapy is essential in type 1 diabetes and should be personalized to optimize glycemic levels.
- Continuous glucose monitoring (CGM) is the preferred method for monitoring glucose, as it protects against hypoglycemia and provides a complete view of glucose levels, both in real time and retrospectively, for optimizing treatment decisions.

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- Regardless of CGM use, all individuals require capillary blood glucose testing supplies and a means of testing blood or urine ketones, with clear instructions on when and how to use these methods.
- $HbA_{1c}$ remains the traditional measure of chronic glucose levels because of its prognostic value.
- Glycemic targets should be personalized.
- Analog insulins are preferred for subcutaneous insulin replacement.
- Automated insulin delivery (AID) systems are the optimal method of insulin delivery if used consistently.
- Diabetes self-management education and support strongly contributes to the effectiveness of multiple daily injection regimens.
- When using multiple daily injections, pen devices are preferred to vials and syringes.

## Monitoring Glycemia

People with type 1 diabetes should have real-time access to information about their glucose levels and trends, including warning alarms and alerts, to help them maintain glucose within the target range and respond promptly to hypoglycemia and hyperglycemia. People with type 1 diabetes and their health care teams should review glucose data as often as needed to maintain blood glucose within recommended ranges.

### *Continuous Glucose Monitoring*

CGM is the standard of care for glucose monitoring in adults with type 1 diabetes. CGM supports the optimization of glycemic levels, reduces rates of hypoglycemia, and improves quality of life (14). A meta-analysis of 24 studies comparing CGM with blood glucose monitoring (BGM) found that mean $HbA_{1c}$ declined by 3 mmol/mol (0.24%), time in range (TIR) increased by 5.6%, and time below range (TBR) decreased by 2.4% (169). CGM has also proven beneficial in reducing the burden of hypoglycemia in older adults with type 1 diabetes (170), as well as severe hypoglycemia in those with impaired awareness of hypoglycemia (IAH) (171).

Historically, two types of CGM devices were available: real-time CGM (rt-CGM), which provides continuous sensor values based on current interstitial glucose levels and trends to a receiver, smartphone, or smartwatch and/or insulin pump, and intermittently scanned CGM, in which the sensor glucose levels are determined by scanning a small reader or smartphone across the transmitter. The latter, however, has been superseded by rt-CGM. CGM devices allow both real-time interaction by the user and retrospective analysis by the user and the health care team. The devices offer predictive and threshold alerts that notify users when they are predicted to reach, or have reached, certain hyperglycemic or hypoglycemic thresholds, facilitating actions that prevent hypoglycemia or significant hyperglycemia, or immediate safety measures such as treatment of hypoglycemia. Additionally, users can respond to trends in glucose, enabling proactive treatment decisions (e.g., to avoid hypoglycemia) rather than reactive responses. Most CGM devices allow users to share their data in real time with a carer or family member, enabling them to receive alerts about dangerous glucose levels.

For retrospective analysis, data from devices can be uploaded to cloud-based programs, allowing users and health care professionals to easily view the data at or between clinic visits, enhancing therapeutic decision-making, understanding and engagement, and behavior change. However, this requires a smartphone and/or a computer with internet connectivity, which may not be readily available in under-resourced settings. CGM downloads should be performed and reviewed at each diabetes management visit. People using CGM should be involved in determining and understanding their personalized treatment goals (mean glucose, TIR, TBR, and other metrics) and, if they are not meeting these goals, establishing what changes could be implemented to help reach them. Examples of CGM target goals are shown in Fig. 4. Standardized glucose reports, such as the ambulatory glucose profile (AGP) and daily tracings, can facilitate these discussions (14).

The accuracy of CGM devices has improved over time and most sensors no longer require confirmatory capillary BGM. The U.S. Food and Drug Administration (FDA) requires CGM systems to meet standards for accuracy and precision prior to approval (172). However, in the EU the requirements for European Conformity (CE) marking are more vague, and proposals have been issued for strengthening them (173). Access to BGM testing may be required, however, when there are concerns that CGM readings may be unreliable, such as when symptoms do not match concurrent CGM glucose values (e.g., falsely low readings due to sensor compression), when CGM devices are warming up or otherwise unavailable, and during correction of hypoglycemia due to the physiological lag between interstitial and blood glucose levels (174).

People with type 1 diabetes should be encouraged to review their own CGM reports regularly and follow their progress over time, contacting their health care team as needed for worsening or changing trends. Users can, for example, set alerts on some CGM devices to inform them of their weekly TIR and how it has changed compared with previous weeks. Such alerts can be helpful motivational tools and prompt the person with diabetes to contact their health care team when needed.

CGM is increasingly used in research and specialist settings in the presymptomatic stage of type 1 diabetes (stages 1 and stage 2) to detect early dysglycemia and refine risk stratification. CGM can identify subtle glucose abnormalities that may precede stage 3 type 1 diabetes and is being explored as a tool to monitor progression and as an outcome measure in prevention trials (21). Routine clinical use of CGM at these stages is not currently recommended, pending further research.

### *Capillary Blood Glucose Monitoring*

Capillary BGM involves the use of a handheld meter that provides a measurement of plasma-calibrated capillary glucose. Frequent BGM monitoring should be advised for individuals not using CGM. In such cases, regular blood glucose measurements are an integral part of diabetes management, helping to guide insulin dosing, food intake, and the prevention of hypoglycemia. All those with type 1 diabetes should have the necessary equipment to undertake BGM, regardless of whether they are using CGM (14). Capillary BGM targets are shown in Table 4.

### *Ketone Measurement*

Ketone bodies are produced when insulin concentrations are too low and/or counterregulatory hormone levels are

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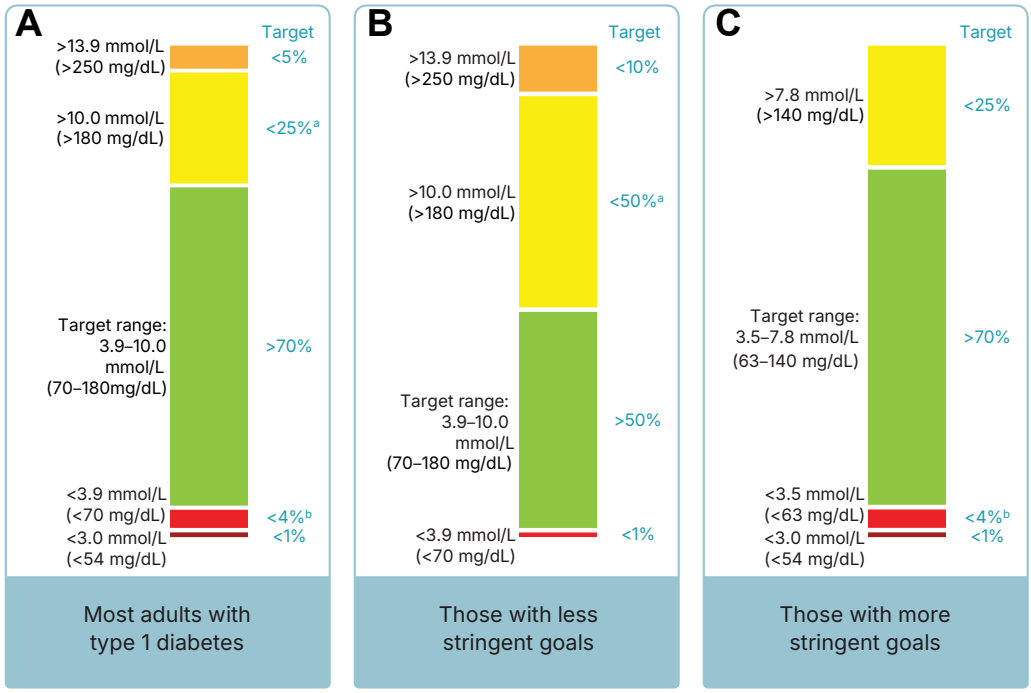


**Figure 4**—A framework for CGM targets for adults with type 1 diabetes. *A*: Most adults with type 1 diabetes. For most adults, the Glucose Management Indicator (GMI) should be <53 mmol/mol (<7.0%) and glycemic variability (%CV) should be <36%, although some studies suggest that lower %CV targets (<33%) provide additional protection against hypoglycemia. *B*: Adults for whom less stringent glycemic targets may be indicated or desired (frailty, limited life expectancy, problematic hypoglycemia). *C*: Adults who are pregnant or for whom more stringent glycemic targets are indicated or desired. In pregnancy, glycemic target ranges are lower than those recommended outside pregnancy. [a]Includes percentage of values >13.9 mmol/L (>250 mg/dL); [b]includes percentage of values <3.0 mmol/L (<54 mg/dL). Adapted and reprinted with permission from Battelino et al. (353).

too high to prevent lipolysis. If left untreated, ketosis can lead to progressive dehydration and DKA. Ketone measurement is important during periods of illness or hyperglycemia to facilitate the management of the hyperglycemia and prevent and/or treat DKA.

Adults with type 1 diabetes should have the ability to undertake ketone measurement at home and be instructed on when to test and how to respond to concerning levels. Measurement can be performed using either blood or urine. Blood measurements are preferred as they are easy to perform, provide quantitative values, and reflect current ketone concentrations, whereas urine ketone measurements lag behind real-time ketone levels (175). However, blood ketone testing is more costly and may not be accessible to all. Methods for continuous ketone measurement are being actively developed (176,177).

**Table 4—Capillary blood glucose and $HbA_{1c}$ targets for most adults with type 1 diabetes**

| Variable | Target value |
|---|---|
| Outside pregnancy | |
| $HbA_{1c}$ | <53 mmol/mol (<7.0%) |
| Preprandial glucose | 4.4–7.2 mmol/L (80–130 mg/dL) |
| 1–2 h postprandial glucose[a] | <10.0 mmol/L (<180 mg/dL) |
| During pregnancy | |
| Fasting | <5.3 mmol/L (<95 mg/dL) |
| 1 h after meals | <7.8 mmol/L (<140 mg/dL) |
| 2 h after meals | <6.7 mmol/L (<120 mg/dL) |

[a]A postprandial glucose target of <7.8 mmol/L (<140 mg/dL) may be recommended if this can be achieved safely. Higher targets are recommended in those with limited life expectancy or where the harms of treatment are greater than the benefits. In some individuals at notably higher risk for level 3 hypoglycemia, it may be necessary to increase the glucose target range to decrease the TBR.

### *$HbA_{1c}$ Measurement*

Monitoring of glucose levels over time has traditionally relied on $HbA_{1c}$, which has been used in most studies demonstrating that improved glycemic management reduces the risks of developing diabetes-related complications (79). There is a strong correlation ($r > 0.9$) between $HbA_{1c}$ and mean blood glucose levels during the preceding 3 months if glucose levels have been stable. However, in some situations, for example when erythrocyte turnover is altered or in the presence of some hemoglobinopathies, $HbA_{1c}$ does not reflect mean glucose, with mismatches of >2.2 mmol/L (>40 mg/dL) between mean glucose determined by CGM and that determined by $HbA_{1c}$ occurring more than 5% of the time (13,175,178). Although there is variability in the relationship between mean glucose and $HbA_{1c}$ between individuals, the relationship within an individual tends to be stable over time (179).

$HbA_{1c}$ is an indicator of mean glucose but does not inform about glycemic variability and hypoglycemia and, therefore, should not be the only method used to evaluate glucose levels in type 1 diabetes

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(179,180). With the widespread adoption of CGM, which provides Glucose Management Indicator (GMI) estimates alongside other detailed metrics, the need for frequent $HbA_{1c}$ testing is being reviewed. There is emerging evidence linking CGM-derived metrics, especially TIR, to the risk of long-term diabetes complications after adjustment for $HbA_{1c}$, supporting a role for CGM in risk assessment beyond $HbA_{1c}$ (181). It has been argued that $HbA_{1c}$ testing could be performed less frequently than the current ADA recommendation of two to four times per year if CGM data are consistently shared with health care providers (13). An $HbA_{1c}$ target of <53 mmol/mol (<7.0%) is appropriate for most adults with type 1 diabetes. Variability in $HbA_{1c}$ has been associated with an increased risk of vascular complications and mortality, regardless of mean $HbA_{1c}$ (182).

## Insulin Therapy

Barring successful β-cell replacement, exogenous insulin is the primary treatment for type 1 diabetes. The ideal insulin replacement regimen maintains blood glucose within recommended ranges while allowing flexibility in terms of mealtimes, carbohydrate consumption, and activity levels. Insulin regimens all comprise two key elements: a basal insulin to restrain gluconeogenesis and ketogenesis in the fasting or postabsorptive state, and a mealtime or bolus insulin to cover food intake and hyperglycemia. These basal and mealtime components can come from either MDI regimens or insulin pump therapy. Regardless of the regimen chosen, glucose monitoring remains a critical and consistent component to guide insulin administration.

### *MDI Regimens*

MDI regimens comprise a subcutaneous basal insulin analog, usually given as a single daily injection, together with separate injections of a mealtime rapid-acting or ultra-rapid-acting insulin analog. Ultra-rapid analogs have a slightly earlier time of onset and peak action than rapid-acting analogs. Compared with rapid-acting analogs, they reduce postprandial hyperglycemia but do not reduce $HbA_{1c}$ or hypoglycemia further (183). Hence, both analog forms are usually referred to as rapid-acting analogs. Basal insulins have evolved from animal-derived and subsequently recombinant human insulin preparations, including intermediate-acting formulations such as neutral protamine Hagedorn (NPH) insulin, to relatively "peakless" basal insulin analogs and newer second-generation analogs that have an extended duration of action, lower pharmacokinetic variability, and more consistent blood insulin levels (183). Compared with the original basal insulin analog glargine U-100, newer basal insulin analogs (insulin glargine U-300, insulin degludec) are associated with fewer episodes of hypoglycemia, a longer duration of action, and more flexible dosing schedules (6). As such, second-generation basal insulin analogs may be preferred in MDI regimens, particularly in those with problematic hypoglycemia.

Once-weekly basal insulin preparations have been developed, with two (insulin icodec and insulin efsitora) having completed phase 3 trials in adults with diabetes. In type 1 diabetes trials, both weekly insulins (compared with degludec as the basal insulin) demonstrated noninferiority for $HbA_{1c}$ lowering but significantly higher rates of level 2 and level 3 hypoglycemia clustering at days in the middle of the dosing interval (184,185). Insulin icodec has been approved by the European Medicines Agency (EMA) for use in the EU, but the U.S. FDA has not approved either icodec or efsitora for people with type 1 diabetes, in part due to concerns about safety. Once-weekly basal insulins are currently not recommended for routine use in people with type 1 diabetes.

The 2021 consensus report (4,5) included a comprehensive section on the management of type 1 diabetes using MDI regimens. No substantive updates were identified and this guidance remains relevant for many individuals with type 1 diabetes, particularly in less well-resourced health care settings. It is therefore not repeated here, and readers seeking detailed information on MDI regimens are encouraged to consult the 2021 consensus report (4,5) and the current ADA Standards of Care (6), which provide practical algorithms for the initiation and titration of multiple daily insulin injections. Other sources of practical advice are available on the IDF (7) and National Institute for Health and Care Excellence (NICE) (8) websites.

***Method of Injection.*** Insulin was traditionally administered using vials and insulin syringes, but since the 1980s insulin pens that use cartridges or that are prefilled and disposable have become the most common mode of insulin administration in high-income countries. Insulin pens administer insulin to the nearest 1 unit (in some cases 0.5 units) increment and have the benefits of increased convenience, easier use, and, perhaps, increased accuracy compared with vial and syringe use (186). Some newer basal insulin analogs no longer come in vials. In lower resource settings or for people without health insurance, insulin pens are more costly and therefore vials and syringes may be used. Whether using pens or syringes, smaller gauge and shorter needles provide almost painless injections and reduce the risk of intramuscular (vs. subcutaneous) injection. Skin thickness is not significantly increased in individuals with overweight or obesity, contrary to common assumptions. Needles as short as 4 mm, injected at a 90° angle, enter the subcutaneous space with minimal risk of intramuscular injection in most adults (187).

***Connected Pens and Bolus Calculators.*** Technology is emerging to help MDI users with the management of insulin doses and timing. Connected, or "smart," insulin pens are either reusable injector pens with embedded electronics or standard pens with an add-on cap. Connected pens record each insulin dose and timestamp and transmit the data wirelessly to a smartphone or cloud-based platform. The systems may include dose reminders, bolus calculators and insulin-on-board tracking, and logging of insulin type and other variables. Some also integrate with CGM. There is a significant negative impact of missed basal and bolus insulin injections on glycemic levels, while greater interaction with smart pen data is associated with improved glucose self-management (188–190). An observational study showed an increase in TIR by up to 2 h per day by switching to a smart pen system (191). However, RCTs of smart pens have not shown significant improvements in glycemic levels. Several smart pens are approved by the U.S. FDA and/or carry the CE mark. A developing area is the incorporation of AI into connected pen platforms that analyze recent data and provide users with optimized insulin dosing advice (192).

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### *Insulin Pumps*

Insulin pumps deliver a continuous supply of rapid-acting analog insulin throughout a 24-h period. Most pumps are worn externally and are connected via tubing to a thin cannula inserted under the skin, although some systems deliver insulin via a pod connected to the cannula without external tubing. Insulin pumps were designed to mimic endogenous insulin kinetics more closely, delivering both basal and bolus components of insulin therapy. The basal component is a low-level infusion of insulin that may vary by time of day based on insulin needs. Bolus doses are larger amounts of insulin given over short periods of time before meals and/or to treat hyperglycemia. Users can manually adjust bolus doses based on carbohydrate intake, current blood glucose levels, and physical activity. Historically, insulin pumps did not integrate with CGM systems and thus users had to monitor glucose with BGM or CGM and perform most actions of the pump manually. Integration of pump functions with CGM data initially led to "threshold low glucose suspend" or "predictive low glucose suspend" features to avert hypoglycemia. Today's pumps integrate more fully with CGM systems to form "hybrid" closed-loop systems (automated basal delivery while most bolus functions are controlled by the user), referred to herein as AID systems (14).

### *AID Systems*

AID systems comprise three components: *1*) an insulin pump to deliver insulin, *2*) a continuous glucose monitor, and *3*) an algorithm that interprets integrated CGM and pump data to determine whether changes in insulin delivery are needed (either more or less insulin).

Continuous glucose monitor data are continuously interpreted by the system to modify basal insulin delivery or trigger the delivery of a correction bolus (in some systems). These systems are generally capable of handling slow drifts in glucose values (up or down) but still require users to inform the pump when they are eating either by entering the carbohydrate count or announcing a meal (depending on the system). Physical exercise also needs to be announced, triggering the algorithm to set a higher glucose target to reduce the risk of hypoglycemia. AID systems have rapidly become the preferred mode of insulin delivery for many people with type 1 diabetes, as studies with different AID systems have consistently shown improved glucose levels (lower $HbA_{1c}$ and/or improved TIR) with reductions or no increases in CGM-detected hypoglycemia (14,193). Furthermore, quality of life is often improved (14).

This is a rapidly evolving area and several AID systems are available in different countries, with varying CGM system compatibility (Table 5). Each system has unique attributes and selection must therefore be personalized. Individuals should be encouraged to explore each option and consider key elements such as the capability of the CGM system and pump, whether the pump has external tubing, the size of the pump, the reservoir size (how much insulin the pump holds), whether the system requires batteries or is rechargeable, whether the system is waterproof, and the ease of self-management. Some systems require a compatible smartphone, which may present a barrier for individuals without access to suitable devices. For the latest information, readers may wish to refer to the "Diabetes Technology" section of the ADA Standards of Care, a frequently updated living document (14), and the PANTHER Program (https://www.pantherprogram.org) and Diabetotech (https://www.diabetotech.com) websites. It is important for both users and clinicians to be familiar with how the algorithms in different AID systems work, and what parameters can and cannot be adjusted to change glycemic outcomes.

Some people with type 1 diabetes employ user-driven open-source or do-it-yourself (DIY) AID systems. These systems use commercially available CGM devices and insulin pumps with open-source software algorithms that integrate CGM device and pump data to control basal insulin delivery and correction doses (194). These systems originated in response to initial delays in the commercial development of AID systems and the perceived limitations of the early commercial systems. In the U.S., the DIY Loop app has been approved by the FDA and is now part of a new AID system (twiist). Regulatory bodies do not allow health care professionals to prescribe algorithms other than Loop, but the hardware for the systems can be prescribed and managed. Health care teams should respect an individual's right to make informed choices about their care and continue to offer support to people using these systems, although support may be limited by a lack of knowledge of the control algorithm settings.

Fully closed-loop AID systems, which require almost no user input even for meals or exercise, are currently being evaluated in clinical trials in both North America and Europe (195). The expectation is that some of these will receive regulatory approval in the next few years. This could allow people with type 1 diabetes to spend more time in the target range, with a minimal risk of hypoglycemia and a reduction in the day-to-day burden of diabetes management.

### *Alternative Routes of Administration*

Although subcutaneous insulin therapy has been the mainstay of treatment for over a century, this mode does not mimic physiological insulin secretion well. Healthy β-cells secrete insulin into the portal circulation at the onset of glucose intake, with approximately 70% of the insulin cleared by the liver and not entering the systemic circulation. Peak blood levels of endogenous insulin occur within 15–30 min after the start of a meal. Conversely, injected subcutaneous rapid-acting insulin enters the systemic circulation with some delay, shows a peak action at around 120 min, and is removed relatively slowly (196,197). Other modes of insulin administration have been designed to achieve pharmacokinetic and pharmacodynamic profiles that more closely resemble the action of endogenous insulin.

An inhaled human insulin is available that consists of powdered human insulin coated onto microparticles for oral inhalation; however, this formulation is only approved in a few countries (198). This delivery mechanism provides a very rapid onset and short duration of action. Compared with mealtime rapid-acting insulin analog injections, inhaled mealtime insulin results in lower post-meal glucose levels and equivalent TIR, hypoglycemia, and time above range (TAR). Cough occurs in about 25% of users, with slight but not significant reductions in forced expiratory volume ($FEV_1$) seen on spirometry (198,199). People using inhaled insulin should be monitored with periodic spirometry because of possible effects on lung function (200).

Implantable intraperitoneal programmable pumps are available in some areas

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**Table 5—Examples of widely used AID systems showing key characteristics and adjustable settings that can be used to optimize glycemic outcomes while in automated mode**

| | MiniMed 780G | Omnipod 5 | Tandem Control-IQ (t:slim X2 or Mobi) | mylife CamAPS FX (YpsoPump) | iLet ACE closed-loop insulin pump | Sequel Med Tech twiist | Diabeloop |
|---|---|---|---|---|---|---|---|
| Characteristic | | | | | | | |
| Infusion mode | Tubing | Tubeless pod | Tubing | Tubing | Tubing | Tubing | Tubing |
| CGM compatibility | MiniMed Simplera Guardian 4 Instinct | Dexcom G6 Dexcom G7 Abbott Libre 2+ | Dexcom G6 Dexcom G7 Abbott Libre 2+ | Dexcom G6 Dexcom G7 Abbott Libre 3+ | Dexcom G6 Dexcom G7 Abbott Libre 3+ | Freestyle Libre 3 Eversense 365 | Dexcom G6 Dexcom G7 |
| Control algorithm | SmartGuard | SmartAdjust | Control-IQ | CamDia APS FX | iLet Dosing Decision | Tidepool Loop | DBLG1, DBLG2 |
| Automation mode | Proportional Integral Derivative controller with insulin feedback + correction bolus | Model Predictive Control and Adaptive | Model Predictive Control + correction bolus | Model Predictive Control and Adaptive | Model Predictive Control and Adaptive | Model Predictive Control | Machine learning + correction bolus |
| Specific features | 7-day infusion set; correction bolus every 5 min | Bolus calculator including basal active insulin | Extended bolus option; multiple profiles for basal, ISF, and I:C ratio; correction bolus every 60 min; simplified bolus | Broad glucose target (4.4–11.1 mmol/L [80–200 mg/dL]); Boost and Ease-Off modes | Carbohydrate counting not required | Emoji to estimate carbohydrate absorption time; maximum basal rate setting; Pre-Meal Preset (correction range for up to 1 h before meals, 3.7–7.2 mmol/L [67–130 mg/dL], typically set lower than the general correction range) | Dana pump or Kaleido pump; Zen mode for temporary target in between exercise mode and standard mode |
| Compatible smart phone required | No | No | Tandem T-slim: no; Tandem Mobi: yes | Yes | No | Yes | No |
| Settings that can be adjusted to optimize glycemic outcomes in automated mode | | | | | | | |
| Insulin/carbohydrate ratio (I:C ratio) | Yes | Yes | Yes | Yes | No | Yes | Yes |
| Insulin sensitivity factor (ISF) | No | Yes | Yes | Yes | No | Yes | Yes |
| Active insulin time | Yes | Yes | No | No | No | No | No |
| Glucose target | Yes | Yes | No | Yes | Yes | Yes | Yes |
| Basal rate | No | No | Yes | No | No | Yes | No |
| Exercise mode[a] | Yes | Yes | Yes | Yes | No | Yes | Yes |
| Sleep mode[a] | No | No | Yes | No | No | No | No |

The table shows systems available at the time of publication but is not an exhaustive list of all currently available devices. [a]Target can be changed with sleep mode (but not independently). Targets always changed with exercise mode. I:C, insulin/carbohydrate; ISF, insulin sensitivity factor.



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in Europe. The pump is embedded in a subcutaneous pocket of the abdominal wall and infuses short-acting (regular) insulin with a stabilizing agent through the peritoneal route (201). Despite not being connected to a CGM device, these systems improve glycemic outcomes compared with subcutaneous insulin pumps, including sustained reductions in $HbA_{1c}$ levels and fewer severe hypoglycemic events (202). Integration with CGM devices may allow fully automated insulin delivery via the peritoneal route (203).

#### *Adverse Effects of Insulin*

The main adverse effect associated with insulin therapy is hypoglycemia, which is discussed in section 9. Insulin may cause body weight gain, which can lead to some people with type 1 diabetes reducing their insulin doses. Sections 13 and 6 on management of overweight and obesity and psychosocial care, respectively, provide more information.

Skin reactions to subcutaneous insulin therapy include local inflammation (often due to either the pH of the insulin solution or additives to the insulin), insulin-induced lipohypertrophy, insulin-induced lipoatrophy, and allergy. Lipohypertrophy is common, typically resulting from repeated use of the same injection or pump site. It contributes to increased insulin requirements and causes glycemic variability, leading to both hyperglycemia and hypoglycemia (204,205). The condition is frequently underdiagnosed, but this can be improved through structured DSMES. In the single-arm Lipohypertrophy Monitoring Study (LIMO), 171 individuals with insulin-treated diabetes were followed prospectively; approximately two-thirds had lipohypertrophy at baseline, with many injecting into affected areas, rotating injection sites incorrectly, and reusing needles. An intervention combining education on injection technique and site rotation with the provision of single-use 4-mm pen needles reduced severe and unexplained hypoglycemia and glycemic variability, although $HbA_{1c}$ did not improve significantly (206). People with type 1 diabetes should receive instruction about proper injection and pump site insertion techniques, including regular site rotation, at insulin initiation and periodically thereafter. Clinicians should inspect and palpate injection and infusion sites at least annually. While ultrasound can detect earlier and smaller lesions than physical examination (204), its added clinical value remains uncertain.

Insulin-induced lipoatrophy has become rare due to improvements in the purity of human and analog insulin. True insulin allergy is rare and typically presents as recurrent local or systemic immediate- or delayed-type hypersensitivity reactions elicited by each injection, with symptoms centered on injection sites. In some cases, switching to a different insulin preparation or changing from MDI to insulin pump therapy may alleviate allergic responses (207).

## SECTION 8: ADJUNCTIVE THERAPIES FOR GLYCEMIC MANAGEMENT

#### *Key Points*

- Evidence supporting the use of adjunctive therapies in type 1 diabetes to improve glycemic management is limited and none are routinely recommended.
- Off-label use of adjunctive therapies is increasing but requires a full understanding of the risks and benefits in an individual with type 1 diabetes.

While insulin therapy is essential for people with type 1 diabetes, maintaining blood glucose within recommended ranges with insulin alone is difficult because of the risks of hypoglycemia, the slow action of "rapid-acting" insulins, insulin resistance, difficulty with carbohydrate counting, and many additional factors. Furthermore, insulin therapy is often associated with undesirable weight gain, which may worsen insulin resistance. Insulin therapy does not address other pathophysiological abnormalities that are present in people with type 1 diabetes, such as α-cell dysfunction, and does not fully protect individuals from an increased risk of CVD. Thus, the potential role of "adjunctive therapies" is to improve glycemic management without increasing hypoglycemia and body weight.

The evidence supporting the use of adjunctive therapies is increasing but is too limited to allow for general recommendations about their use. However, these therapies can be considered in individual cases (Table 6); however, before these drugs are prescribed, insulin therapy should be optimized. The use of incretin-based drugs and sodium–glucose cotransporter 2 (SGLT2) inhibitors for obesity and cardiovascular risk management is described in sections 12 and 13.

### Metformin

The effect of metformin on glucose levels has been evaluated in numerous small trials in people with type 1 diabetes. A recently updated meta-analysis reported modest benefits for $HbA_{1c}$ and reductions in total daily insulin dose, BMI, and total cholesterol (208). However, the largest and longest study to date, involving 428 people with type 1 diabetes treated for 3 years, found no difference in the primary end point of changes in mean carotid intima–media thickness (a marker of CVD risk). Effects on $HbA_{1c}$ were minimal and not sustained, weight reduction was modest (∼1 kg) and there was no significant change in total daily insulin dose (209). Thus, metformin therapy is generally not recommended for people with type 1 diabetes, although it may be considered on an individual basis.

### Pramlintide

Pramlintide, an amylin analog, is the only approved adjunctive therapy to insulin in the U.S.; however, it is not approved in Europe. Injection prior to meals suppresses glucagon secretion, delays gastric emptying, and promotes satiety (210–213). Clinical trials have shown a reduction in $HbA_{1c}$ (3–4 mmol/mol [0.3–0.4%]) and modest (∼1 kg) weight loss with pramlintide (214–217). Because of its adverse effects and the need for additional injections, clinical uptake of pramlintide has been limited. It was withdrawn from the market in the mid-2010s and is no longer clinically available. However, coformulations of amylin with insulin are currently in development, and the use of pramlintide in pumps or AID systems is also being explored.

### GLP-1 Receptor Agonists and Dual GLP-1 Receptor/GIP Receptor Agonists

Glucagon-like peptide 1 (GLP-1) receptor agonists have been explored in people with type 1 diabetes for two indications. The first aimed to ameliorate β-cell decline at the time of diagnosis, and there are ongoing trials of this approach. In one study of 308 people with recently

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**Table 6—Adjunctive therapies for glycemic management in type 1 diabetes**

| Variable | Metformin | Pramlintide | GLP-1 ± GIP receptor agonists | SGLT2 or SGLT1/2 inhibitors |
|---|---|---|---|---|
| $HbA_{1c}$ reduction | 1–7 mmol/mol (0.1– 0.7%) | 3–4 mmol/mol (0.3–0.4%) | 2–4 mmol/mol (0.2–0.4%) | 2–4 mmol/mol (0.2–0.4%) |
| Fasting glucose | Minimal effect | No effect | Minimal effect | Modest decrease (0.8 mmol/L [15 mg/dL]) |
| Postprandial glucose | Minimal effect | Significant decrease | Modest decrease | Modest decrease |
| TIR | No data | No data | No data | Increased (∼12% at higher doses) |
| Insulin dose | Mean reduction of $-0.44$ U $kg^{-1}$ $day^{-1}$ | Mealtime reductions | Predominantly mealtime reductions | Mealtime and basal reductions (∼10% total reduction) |
| Body weight or BMI | BMI reduction ($-0.71$ kg/$m^2$) | Modest weight decrease (∼1 kg) | Significant weight decrease (∼5–15 kg) | Moderate weight decrease (2–3 kg) |
| Systolic blood pressure | No change | No change | 4 mmHg decrease, increase in heart rate | 3–4 mmHg decrease |
| Hypoglycemia | Low risk | Potential increase in level 3 hypoglycemia if prandial insulin doses are not decreased | Increase in hypoglycemia | Low risk |
| Side effects | GI side effects | GI side effects | GI side effects; increase in ketosis | Genital mycotic infections; 2.5- to 6.0-fold increased risk of DKA; dehydration |
| Approval status for type 1 diabetes in EU/U.S. | Not approved | U.S. approved | Not approved | Not approved |
| Cardiovascular benefits in other populations, including type 2 diabetes | Yes | No | Yes | Yes |

EU, European Union; GI, gastrointestinal; GIP, glucose-dependent insulinotropic polypeptide; GLP-1, glucagon-like peptide 1.

diagnosed type 1 diabetes, liraglutide, when used in combination with anti-IL-21 antibody, preserved β-cell function (218). The second indication is as an adjunctive therapy in established type 1 diabetes by blunting glucagon secretion, slowing gastric emptying, and promoting satiety and thereby weight loss (219). The largest clinical trials in people with type 1 diabetes have been conducted with liraglutide and showed, at daily doses of 1.8 mg, decreases in $HbA_{1c}$ (2–4 mmol/mol [0.2–0.4%]), weight (∼5 kg), and insulin doses (220,221). However, increased rates of hypoglycemia and ketosis were also found. A recent study found that semaglutide is safe in people using AID systems, lowering $HbA_{1c}$ by 3 mmol/mol (0.3%) and body weight by 8.8 kg (222), while two studies reported that the dual GLP-1/glucose-dependent insulinotropic polypeptide (GIP) receptor agonist tirzepatide significantly reduced $HbA_{1c}$ and body weight in adults with type 1 diabetes (223,224). Given the effect on insulin requirements, users should be provided with careful advice about insulin dose adjustment when GLP-1 receptor agonists or dual GLP-1/GIP receptor agonists are started or stopped.

### SGLT Inhibitors

In several phase 3 programs in people with type 1 diabetes, the use of SGLT1 or SGLT1/2 inhibitors has been shown to reduce $HbA_{1c}$, improve TIR, reduce body weight, and improve blood pressure (225). However, a meta-analysis of 20 studies including 7,183 participants reported that individuals treated with SGLT1 or dual SGLT1/2 inhibitors had a 2.57- to 5.96-fold higher incidence of DKA than those receiving placebo (226). This increased rate of DKA led to the U.S. FDA's rejection of market authorization for their use in type 1 diabetes. Although the EMA previously approved low-dose dapagliflozin (5 mg) and sotagliflozin (200 mg) as an adjunctive therapy for type 1 diabetes in those with a BMI ≥27 kg/$m^2$, their market authorization was subsequently withdrawn on the request of the market authorization holders (227). While no risk mitigation strategies have been proven to lower the risk of DKA, a consensus statement on SGLT2 inhibitors and DKA suggested careful patient selection, appropriate insulin dose adjustment to avoid insulinopenia, starting with a low dose of SGLT2 inhibitors, and regular ketone measurements with prompt action to address elevated values as sensible precautions aimed at preventing DKA (228). The development and clinical use of continuous ketone monitors may help inform future approaches to reduce the risk of DKA associated with SGLT inhibitors in people with type 1 diabetes (177); however, this potential role is speculative and would require formal evaluation.

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## SECTION 9: ACUTE METABOLIC EMERGENCIES

***Key Points***

- Clinicians should proactively identify impaired awareness of hypoglycemia (IAH) using validated questionnaires or simple questions such as "Can you always feel when your blood glucose is low?" and "At what blood glucose level do you feel symptoms?"
- IAH is a significant risk factor for severe hypoglycemia, but the risk can be reduced through use of continuous glucose monitoring, titrated insulin regimens that mimic physiological endogenous insulin secretion, and structured or personalized education.
- Risk factors for diabetic ketoacidosis (DKA) include younger age, lower socioeconomic status, infection, intercurrent illness, psychological stress, omission of or under-dosing of insulin, and adjunctive use of sodium–glucose cotransporter 2 (SGLT2) inhibitors.
- DKA prevention strategies include diabetes self-management education and support and awareness of sick-day advice, including intensified glucose and ketone monitoring.

### Hypoglycemia

Hypoglycemia, the most important limiting factor in the glycemic management of type 1 diabetes (13), is classified into three levels:

- Level 1: plasma or interstitial glucose concentrations <3.9 mmol/L (<70 mg/dL) and ≥3.0 mmol/L (≥54 mg/dL). This is an alert threshold at which people on insulin should take action.
- Level 2: plasma or interstitial glucose concentrations <3.0 mmol/L (<54 mg/dL). Level 2 hypoglycemia is considered clinically important hypoglycemia.
- Level 3: hypoglycemia characterized by an altered mental state and/or physical status needing the intervention of a third party for recovery. Level 3 hypoglycemia is also called severe hypoglycemia.

#### *Epidemiology of and Risk Factors for Hypoglycemia in Type 1 Diabetes*

Rates of hypoglycemia are generally determined from self-report, CGM data (for level 1 or level 2 hypoglycemia), and data from hospitals and emergency departments. CGM data can include false-positive hypoglycemia, including compression lows, and should be validated. Hospital and emergency department data primarily describe, but likely underestimate, severe hypoglycemia. Hypoglycemia, including severe episodes, remains troublingly common in people with type 1 diabetes. In a study of approximately 67,000 adults with type 1 diabetes, adjusted rates of severe hypoglycemic emergencies increased from 25.7 to 32.9/1,000 person-years between 2011 and 2019 and then decreased to 25.6/1,000 person-years in 2020. Although the trends were not statistically significant, these analyses suggest that rates of severe hypoglycemia are not declining despite advances in therapies (229). In a cross-sectional survey of adults with type 1 diabetes (92% using CGM and almost half using AID systems), 20% reported having had at least one episode of severe hypoglycemia in the past year, with 12% reporting at least two episodes. Although a reported history of severe hypoglycemia was lower with use of technology (e.g., 34% of nonusers of CGM vs. 18% of CGM users), 16.6% of those using AID systems still reported an episode within the past year. However, the timing of initiation of AID use was not ascertained (230).

Risks for hypoglycemia, particularly level 3 hypoglycemia, include a longer duration of diabetes, older age, a history of recent level 2 or level 3 hypoglycemia, high glycemic variability, alcohol ingestion, exercise, a lower education level, a lower household income, chronic kidney disease, and IAH (13). IAH is the reduced ability to recognize low blood glucose levels, typically due to loss of counterregulatory hormone responses and their associated symptoms (231). Confusion or loss of consciousness may be the first sign of hypoglycemia, pre-empting appropriate corrective behaviors. The prevalence of IAH is estimated to be 25–30% in people with type 1 diabetes but is likely to be underestimated based on CGM data (232). IAH markedly increases the risk of severe hypoglycemia. The subsequent fear of hypoglycemia may lead people with diabetes to intentionally omit insulin doses or relax their glycemic targets in an effort to prevent the reoccurrence of hypoglycemia. IAH is associated with, but not fully explained by, autonomic neuropathy (233). It can be induced or worsened by recurrent hypoglycemia and alcohol use (13). Although most hypoglycemic episodes in people with type 1 diabetes result from insulin mismatch, clinicians should be aware that autoimmune thyroid and adrenal disorders and undiagnosed celiac disease, which are more common in this population, are potential causes of unexplained hypoglycemia.

Diabetes health care professionals should proactively ask people with type 1 diabetes whether, and at what glucose level, they feel hypoglycemia in order to identify IAH and adjust individual glucose targets to reduce the risk of severe hypoglycemia. Validated questionnaires, such as the Clarke (234), Pedersen-Bjergaard (235), and Gold (236) questionnaires and the Hypoglycemia Awareness Questionnaire (HypoA-Q) (237) can also identify IAH. However, simple questions such as "Can you always feel when your blood glucose is low?" and "At what blood glucose level do you feel symptoms?" can be used to identify IAH and the risk of severe hypoglycemia (13).

Significant discrepancies have been shown between continuous glucose monitor-detected and patient-reported hypoglycemia (174); hence, both modes of capturing hypoglycemia occurrence should be considered, especially because only patient-reported hypoglycemia has been shown to have a significant impact on daily functioning (238).

#### *Consequences and Prevention of Hypoglycemia*

Hypoglycemia has significant impacts on quality of life and psychological well-being. Severe hypoglycemia may lead to injury to the person with diabetes or to others, for example when driving. Hypoglycemia in type 1 diabetes is estimated to account for more than 8% of deaths among those aged <56 years (239). The long-term association of severe hypoglycemia with subsequent cognitive function has been examined in the DCCT-EDIC cohort. In these analyses, severe hypoglycemia in younger or middle-aged adults did not appear to affect neurocognitive function after 18 years of follow-up (240). However, after 32 years of follow-up (median age 59 years), more episodes of severe hypoglycemia were independently associated with greater decrements in psychomotor and mental efficiency (148).

Several strategies can be used to reduce the risk of clinically significant or severe hypoglycemia. Structured education

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programs, such as Dose Adjustment For Normal Eating (DAFNE) and Blood Glucose Awareness Training (BGAT), which provide informed support for appropriate glucose monitoring and active insulin dose self-adjustment, have been shown to reduce severe hypoglycemia rates in those at high risk (241). As these specific programs are not widely available, periodic DSMES that addresses modifiable risks of hypoglycemia and optimization of insulin therapy is indicated in all adults with type 1 diabetes, with enhanced education and support provided for those with problematic episodes.

The use of insulin analogs and carefully titrated basal–bolus regimens is standard of care in people with type 1 diabetes, due to their closer mimicry of physiological endogenous insulin secretion and reduced risks of hypoglycemia. Compared with BGM, CGM has been shown to reduce TBR and episodes of severe hypoglycemia in those at high risk of hypoglycemia (170,171,241). AID systems have potential to detect impending or early hypoglycemia and to protect against more severe events. AID systems are associated with further reductions in CGM-detected hypoglycemia compared with use of CGM and insulin pumps in open-loop mode, including in populations with high rates of severe hypoglycemia (242). Despite evidence that AID technology reduces the risk of nonsevere hypoglycemia, randomized and real-world studies have not generally demonstrated reductions in episodes of severe hypoglycemia, with occasional exceptions (243). This may be due to statistical power issues, participant selection, or lack of sensitivity for the detection of severe hypoglycemia.

Early clinical physiology studies suggested that strict avoidance of hypoglycemia helped restore hypoglycemia awareness (233). However, several clinical trials have not shown reductions in rates of IAH with CGM use despite a reduced incidence of hypoglycemia (241). In a survey of adults with type 1 diabetes, rates of IAH (measured using the Gold questionnaire [236]) were about 30% in all subgroups (CGM users vs. BGM users, AID vs. open-loop pump or MDI use), despite differences in rates of reported severe hypoglycemia episodes (230).

In some situations, it may be necessary to increase the glucose target range if hypoglycemia cannot be rectified through other means. Intractable severe hypoglycemia is an indication for islet or pancreas transplantation (see section 10).

#### *Treatment of Hypoglycemia*

The standard recommendation for correcting level 1 or level 2 hypoglycemia is the oral intake of approximately 15 g of glucose or equivalent simple carbohydrate when the capillary or interstitial blood glucose concentration is <3.9 mmol/L (<70 mg/dL). This should be repeated every 15 min until any symptoms have resolved and the blood glucose level is >3.9 mmol/L (>70 mg/dL). As there may be a 5- to 15-min lag between changes in capillary blood glucose and interstitial glucose, CGM may show delayed detection of the restoration of normoglycemia. For those with a tendency toward over-treatment, the use of BGM is recommended to determine when hypoglycemia has resolved (13). Less glucose (5–10 g) may be needed to correct hypoglycemia while using AID, because the delivery system should have already reduced or stopped basal insulin delivery, and because overcorrection may trigger additional insulin delivery (244,245).

When there is a reduced level of consciousness, oral glucose intake is contraindicated because of the risk of aspiration. Instead, caregivers or bystanders should administer glucagon via subcutaneous or intramuscular injection or via nasal delivery. Intravenous glucose injection is a possible alternative for health care professionals in cases of level 3 hypoglycemia. For many years, glucagon was dispensed as a powder and separate diluent that required mixing prior to administration. Newer forms of glucagon that are stable in solution and ready to inject, or that can be given intranasally, are easier for bystanders to use and may lead to more rapid correction of severe hypoglycemia (13). However, these preparations may be significantly more expensive and may not be available in all locations.

After the acute symptoms have resolved, a further 20 g of carbohydrate as part of a snack or meal may need to be ingested if there is still significant insulin on board or if exercise was the cause of the hypoglycemic episode. If possible, the cause of the episode should be ascertained to determine preventive actions for future episodes.

### Diabetic Ketoacidosis

DKA is a life-threatening but preventable acute complication of type 1 diabetes, characterized by hyperglycemia, metabolic acidosis, and ketosis. Occasionally, DKA can be present when glucose levels are normal or only minimally elevated (<11.1 mmol/L [<200 mg/dL]); this "euglycemic" DKA is more common with pregnancy, insulin pump use, or adjunctive use of SGLT2 inhibitors. The underlying cause of DKA is insulin deficiency, either absolute (new diagnosis of type 1 diabetes or omission of insulin in those with diagnosed disease) or relative (increased counterregulatory hormones due to infection or other stressors without an adequate increase in insulin doses) (22). Omission, or inadequate doses, of insulin may be iatrogenic, such as when clinicians mischaracterize adult type 1 diabetes as the more prevalent type 2 diabetes.

The prevalence of DKA and risk factors for its development have been less well studied in adults with type 1 diabetes than in children. In the U.S., national surveillance of emergency department visits and hospital admissions suggests a rate of 28 cases per 1,000 adults with diabetes per year, with a worrying increase in emergency department visits and admissions for DKA since 2009 (246). In Denmark, the incidence of DKA in adults with type 1 diabetes doubled between 1996 and 2008, with a subsequent minor decrease from 2008 to 2020 (247). In a European (predominantly Germany and Austria) registry, adults with type 1 diabetes had DKA at a rate of 2.5 per 100 patient-years (248).

DKA is more common in younger adults (aged 18–44 years) with type 1 diabetes than in older individuals, and in people who are uninsured or of lower socioeconomic status. DKA can be the presenting manifestation of type 1 diabetes in 6–21% of adults at the time of diagnosis. In those with known diabetes, risk factors include infections, intercurrent illness, psychological stress, and omission or underdosing of insulin (22). A subset of individuals with type 1 diabetes has recurrent episodes of DKA, with some studies suggesting that 22% of adults admitted for DKA in the U.S. are readmitted for the same diagnosis within the following year, 14% of whom have four or more subsequent admissions.

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Recurrent DKA is more common in younger adults, women, and those of low socioeconomic status (249). People with recurrent DKA frequently experience high levels of anxiety and diabetes-related distress, difficulties with emotion regulation, and personality dysfunction (250).

The use of SGLT inhibitors in adults with type 1 diabetes increases the risk of DKA by 2.57- to 5.96-fold, even in carefully selected and monitored participants in clinical trials (226). About a third of cases of DKA in the setting of SGLT inhibitor use are euglycemic DKA, suggesting that glucose monitoring alone is insufficient for detection (251). The integration of continuous ketone measurement into CGM systems may provide additional benefits in the future.

DSMES is an effective tool in reducing DKA risk. Additional medical and behavioral health interventions, including home ketone testing and psychosocial support, are often needed. Telemedicine has the potential to reach populations with decreased access to care, and 24-h access to advice about managing hyperglycemia and ketosis or ketonemia at home can reduce the risk of hospital admission (22).

A detailed description of the management of DKA is beyond the scope of this report, but the general principles of treatment are the replacement of fluid, insulin, and potassium. Addressing the underlying cause(s) and contributing factors is essential, as is a careful plan for outpatient follow-up. For further information regarding treatment of DKA, refer to the recent consensus report developed by ADA, EASD, and other organizations (22).

#### *Sick-Day and Illness Management*

Stressful events, including illness, may affect glucose levels and increase the risk of DKA. More frequent glucose and ketone measurements are necessary to guide insulin dose adjustments. Individuals should devise a sick-day management plan in consultation with their health care professional (20). Such protocols should specify the amounts and types of fluids and carbohydrates to consume, how often to monitor glucose and ketone levels, how and when to give supplemental insulin, and the circumstances under which a person with diabetes should seek urgent medical care (13). Those who use AID systems should be aware that the underlying algorithms may not be able to adapt quickly to marked increases in insulin needs, such as following initiation of glucocorticoid therapy or during severe illness. Conversion to open-loop mode may be needed.

## SECTION 10: PRESERVATION AND REPLACEMENT OF β-CELL FUNCTION

#### *Key Points*

- Current strategies aim to preserve endogenous β-cell function through immunomodulatory and metabolic therapies in early-stage type 1 diabetes.
- Clinical approaches to β-cell replacement include whole-organ pancreas and pancreatic islet transplantation.
- Evolving diabetes technologies are impacting patient eligibility and the role of transplantation in the current treatment landscape.
- Emerging alternatives to donor-derived islets include stem cell-based therapies and porcine islet xenotransplantation.

### Prevention of Immune Destruction to Preserve β-Cell Function

Several immunotherapy approaches are being evaluated for their potential use in stage 1 or stage 2 type 1 diabetes to prevent stage 3 clinical type 1 diabetes, and for the preservation of β-cell function before and shortly after the onset of stage 3 clinical type 1 diabetes (252). To date, the most promising results from clinical trials have been seen with the anti-CD3 monoclonal antibody teplizumab (253), low-dose antithymocyte globulin (ATG) (254), anti-TNF-α drug golimumab (255), and JAK inhibitor baricitinib (256). These immunotherapies can preserve β-cell function in recent-onset type 1 diabetes, and, in addition, teplizumab delays the clinical onset of type 1 diabetes (257).

Teplizumab is the first U.S. FDA-approved disease-modifying therapy for type 1 diabetes that delays the onset of stage 3 type 1 diabetes. Although approval is for individuals aged ≥8 years who are in stage 2 of the disease, it should be noted that most study participants were young (median age 14 years) and that type 1 diabetes has a slower onset in older adults. Clinical trials have shown that a single 14-day course of teplizumab can delay the onset of clinical type 1 diabetes by a median of 2–3 years in high-risk individuals (78).

Several trials are underway with the aim of not only preserving but also improving β-cell function, and of interrupting the type 1 diabetes disease process sufficiently to prevent the development of clinical disease (258,259). Family members of individuals with type 1 diabetes are being encouraged to undergo screening for islet autoantibodies. Many countries have established networks that facilitate screening and follow people with the potential to be enrolled in clinical trials (260–263).

### Replacement of β-Cells

Whole-organ pancreas transplantation and pancreatic islet transplantation remain the primary clinical methods for β-cell replacement in individuals with type 1 diabetes. Both approaches have demonstrated efficacy in achieving normoglycemia, preventing hypoglycemia, and potentially stabilizing or reversing diabetes-related complications (264–269). However, the necessity for chronic systemic immunosuppression to prevent allogeneic rejection necessitates a careful assessment of the risk/benefit ratio, incorporating both medical and psychological factors (270). Both whole-organ pancreas and pancreatic islet transplantation continue to evolve as viable therapeutic options for individuals with type 1 diabetes. Recent developments have focused on enhancing the efficacy and accessibility of islet transplantation through the exploitation of alternative cell sources and strategies to reduce or avoid the need for immunosuppression (271,272).

#### *Whole-Organ Pancreas Transplantation*

The majority of pancreas transplants are performed simultaneously with kidney transplants (simultaneous pancreas and kidney [SPK] transplantation). This represents the standard treatment for individuals with type 1 diabetes and end-stage renal disease, provided there are no contraindications such as malignancies, chronic infections, inadequate self-management, or severe cardiovascular conditions. SPK transplants have demonstrated a 5-year pancreas graft survival rate of >80%, surpassing the outcomes of pancreas transplants alone (PTA) or pancreas after kidney transplants

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(264,266). Recipients of SPK transplants often experience significant amelioration of problematic hypoglycemia for extended periods (266,273,274).

PTA is typically considered for younger individuals (under 50 years of age) without obesity (BMI <30 kg/m$^2$) or coronary artery disease (275). These criteria help minimize operative mortality to <1% and reduce early technical pancreas graft loss to <10% (264,275). The primary indications for PTA include a history of frequent, acute, and severe metabolic complications (e.g., hypoglycemia, hyperglycemia, DKA), significant clinical and emotional challenges with exogenous insulin therapy, and consistent failure of insulin-based management, including technological aids (276).

#### *Pancreatic Islet Transplantation*

Pancreatic islet transplantation, a less invasive procedure, is indicated for individuals with excessive glycemic lability and frequent severe hypoglycemia despite optimal medical therapy (277). This approach allows for the inclusion of older people and those with coronary artery disease who may not be suitable candidates for whole-pancreas transplantation (278–281). Advancements in patient selection and protocol optimization have led to substantial clinical improvements, leading to the maintenance of insulin independence for 5 years in approximately 50% of recipients (281,282). Beyond achieving insulin independence, recent multicenter clinical trials have emphasized the importance of attaining $HbA_{1c}$ <53 mmol/mol (<7.0%) alongside the elimination of severe hypoglycemia as primary end points, reflecting clinically relevant goals. These outcomes have been associated with improved patient-reported outcomes (265,282–285).

#### *Impact of Advancements in Diabetes Technology on Transplant Eligibility*

The continuous advancements in diabetes technology, particularly AID systems, have significantly improved glycemic management. As a result, the number of individuals who meet the strict eligibility criteria for PTA or islet transplantation alone (ITA) has declined. These technological improvements offer a less invasive and lower-risk alternative to transplantation for many people, shifting the risk–benefit balance and reserving PTA and ITA for those with the most severe glycemic instability or insulin resistance that cannot be managed with current diabetes technology (269,286).

#### *Stem Cell Strategies*

A major limiting factor for pancreas or islet transplantation is a limited supply of organs, given the need for cadaver donors. To solve the problem of availability, options under investigation include the use of stem cell–derived islets (287) and xenotransplantation with porcine islets (288,289). Stem cell strategies have used either patient-specific stem cells or universal allogeneic cells. In the former, the patient's own stem cells are reprogrammed or transdifferentiated to become β-cells (290). By contrast, generic allogeneic cells may be centrally produced from a bank of human embryonic stem cells (hESCs) or of induced pluripotent stem cells (iPSCs) and used for multiple recipients (291). One of the key issues is protecting the cells from immune attack, both rejection and recurrent autoimmunity. Three general strategies are being investigated: *1*) the use of immunomodulatory drugs, *2*) the use of a physical barrier (e.g., encapsulation) (292), and *3*) gene editing for immune evasion and/or immune protection (293). Both academic and commercial groups are pursuing these approaches, and some are already in clinical trials. Nonetheless, for stem cell–based strategies, there remain both challenges and opportunities for achieving successful reversal of type 1 diabetes (272).

### Regeneration of β-Cells

Several approaches have been studied with the aim of generating or regenerating β-cells, with most studies conducted in isolated cell systems or in animal models (294–296). These approaches include the use of DYRK1A inhibitors, menin inhibitors, and a combination of a GLP-1 receptor agonist, gastrin, and GABA. Clinical trials are expected to begin in the near future.

## SECTION 11: SCREENING FOR MICROVASCULAR COMPLICATIONS

#### *Key Points*

- Screening for microvascular complications in type 1 diabetes does not need to be performed until 5 years after diagnosis.
- Regular assessment for retinopathy, nephropathy, and neuropathy enables early detection and intervention.
- Fundus photography, a 10-g monofilament test, urinary albumin/creatinine ratio, and eGFR testing are pivotal screening tests.
- Screening frequency should be personalized based on findings, glycemic levels, and comorbidities.
- Optimizing glycemic levels and blood pressure remains central to preventing the progression of complications.

As there are many guidelines available on the management of microvascular complications (16,17), this section focuses on the detection of microvascular complications.

### Diabetic Retinopathy

In the modern era of type 1 diabetes management, the incidence and prevalence of diabetic retinopathy has decreased. In a comparison of the U.S. T1D Exchange (*n* = 1,283, mean diabetes duration 32 years) and the German/Austrian DPV (*n* = 2014, diabetes duration 29 years) registries, diabetic retinopathy was reported in 34% and 40% of participants, respectively (297). In the U.S., this compares with a prevalence of 75–82% in the early 2000s (298).

Retinal photography with remote reading by experts can enable screening in areas where qualified eye care professionals are not readily available (299,300) and increase efficiency with reduced costs where these professionals are available (17). Retinal photography can be performed within primary diabetes health care settings and is patient friendly, as pupil dilation is not always required. Images should be interpreted by a trained eye care professional or reading center technician or by approved AI programs. If sight-threatening diabetic retinopathy is noted on screening, referral to an ophthalmologist is recommended. Alternatively, a comprehensive eye examination can also be performed by an ophthalmologist or optometrist.

The initial retinal examination should be performed within 5 years of the onset of type 1 diabetes, with subsequent examinations generally recommended annually for those without or with mild diabetic retinopathy (17). Examinations every 1–2 years or even less frequently may be cost-effective after one or more normal eye examinations (301). More frequent examinations will

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be required if retinopathy is progressing and risk factors, such as hyperglycemia and hypertension, are not adequately managed. Similarly, for advanced diabetic retinopathy or macular edema, more frequent examinations are recommended.

Treatment by primary health care providers should include optimizing glycemic and blood pressure management to reduce the risk or slow the progression of diabetic retinopathy. A recent meta-analysis of fibrates suggested that these drugs reduce the incidence and long-term progression of retinopathy; however, only one of the 17 studies was undertaken in people with type 1 diabetes (302). Given the limited evidence in people with type 1 diabetes, fibrates are not recommended as standard treatment for retinopathy (17).

### Diabetic Kidney Disease

Diabetic kidney disease has historically impacted 30–40% of individuals with type 1 diabetes (303); however, with better treatment of glucose levels and blood pressure, the prevalence is decreasing in some (304), but not all (305,306), settings. One report from the U.S. noted a weighted estimate of 21.5%; however, there are large variations in the burden of diabetic kidney disease around the world, largely due to economic factors (307).

Screening for albuminuria should be performed by assessing the urinary albumin/creatinine ratio (uACR) in a random spot urine sample (17). In case of elevated uACR, confirmation by repeated examination is needed. A normal uACR is defined as <3 mg/mmol (<30 mg/g), moderately elevated albuminuria is defined as a uACR ≥3–30 mg/mmol (>30–300 mg/g), and severely elevated albuminuria is defined as a uACR ≥30 mg/mmol (≥300 mg/g). Because of high biological variability (>20%) in urinary albumin excretion, a diagnosis of elevated albuminuria should be made only if at least two of three uACR measurements collected over a 3- to 6-month period are abnormal, after excluding other causes such as glomerular disease (by urinalysis) and orthostatic proteinuria, particularly in young adults (308). Furthermore transient elevations in uACR may occur due to exercise, intercurrent illness, urinary tract infection, dehydration, menstruation, or collection and analytical factors.

The eGFR is usually calculated from serum creatinine using a validated formula (17). An eGFR persistently <60 mL/min per 1.73 $m^2$ and/or a uACR of >3 mg/mmol (>30 mg/mL) is considered abnormal.

The current recommendation is to assess uACR and eGFR in adults with type 1 diabetes yearly in those with a diabetes duration of ≥5 years (303), although less frequent measurement may be considered. Treatment of established moderately elevated albuminuria starts with renin–angiotensin–aldosterone system (RAAS) inhibition. Recent evidence indicates that finerenone produces a significantly greater reduction in uACR than placebo (309). Individuals should be referred to a nephrologist if urinary albumin levels increase progressively, there is a >30% decrease in eGFR following initiation of hemodynamically active therapy (RAAS inhibitors, mineralocorticoid receptor antagonists, or SGLT2 inhibitors,) or eGFR is <30 mL/min per 1.73 $m^2$ (310).

### Neuropathy

Recent Danish data show a decreasing and low risk of diabetes-related foot complications in type 1 diabetes, with a cumulative 3-year risk of 0.2% in low-risk individuals (around 50%) and 3.9% in high-risk individuals (311). However, changes in prevalence in other countries are less well documented.

Yearly screening for peripheral neuropathy, also termed distal symmetrical polyneuropathy, is recommended from 5 years after diagnosis (17,312), although recent data strongly suggest that screening intervals can be prolonged in low-risk individuals (311). In low-risk individuals, screening for loss of protective sensibility should be performed using a 10-g monofilament. Full assessment for peripheral neuropathy includes a careful history and assessment of either temperature or pinprick sensation (for small-fiber function) and vibration sensation using a 128-Hz tuning fork (for large-fiber function) (17,312). The most common early symptoms are induced by the involvement of small fibers and include pain and dysesthesia (unpleasant sensations of burning and tingling). The involvement of large fibers may cause balance issues, numbness, and loss of protective sensation. Importantly, up to 50% of diabetic peripheral neuropathy may be asymptomatic. If this is not recognized and preventive foot care is not implemented, there is a higher risk of diabetes-related foot ulcers and amputations.

While there are many etiologies of peripheral neuropathy, for those with type 1 diabetes it is important to consider hypothyroidism and vitamin $B_{12}$ deficiency, which are more often seen in this population (313). Other causes should be considered where clinically indicated.

Awareness of diabetic autonomic neuropathy is especially relevant if other microvascular complications are present, specifically diabetic retinopathy and peripheral neuropathy. History includes asking about dizziness, light-headedness or feeling faint on standing, syncope, early satiety, erectile dysfunction, changes in sweating patterns (especially gustatory sweating), or dry cracked skin of the extremities. On examination, resting tachycardia (after ruling out hyperthyroidism and other causes of tachycardia), orthostatic hypotension, or evidence of peripheral dryness or cracking of the skin may be found. While a resting heart rate greater than 100 bpm is generally noted early in those with autonomic neuropathy and can be used in early screening (314), more detailed testing such as measurement of heart rate variability using electrocardiography, heart rate response to standing, heart rate response to a Valsalva maneuver, and systolic response to standing are required for a definitive diagnosis (315).

## SECTION 12: CARDIOVASCULAR RISK MANAGEMENT

***Key Points***

- Cardiovascular risk is substantially increased in adults with type 1 diabetes and requires proactive management.
- Cardiovascular risk management in type 1 diabetes includes striving for optimal glycemic, blood pressure, cholesterol, and body weight management and promoting smoking cessation.
- Studies undertaken in other populations including people with type 2 diabetes suggest that there may be a role for glucagon-like peptide 1 (GLP-1)–based drugs and sodium–glucose cotransporter 2 (SGLT2) inhibitors in preventing CVD in people with type 1 diabetes.

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The prevention of CVD in people with type 1 diabetes extends beyond glycemic management to include the optimal management of blood pressure and use of lipid-lowering medication. There is an absence of cardiovascular outcome studies in people with type 1 diabetes, and so extrapolation from studies performed in other populations, mainly those with type 2 diabetes, is unavoidable (15,316). However, there is no reason to believe that preventive treatment in people with type 1 diabetes should be less needed or less effective.

### Glycemia

In the EDIC cohort study following the DCCT randomized trial, 42% and 30% reductions in cardiovascular events at 17 years and after 30 years, respectively, were seen in those originally assigned to the intensive therapy cohort compared with those originally assigned to conventional therapy (80,317).

The benefits of GLP-1 receptor agonists and SGLT2 inhibitors in reducing heart failure, cardiovascular mortality, renal function decline, and other emerging outcomes have been shown in diverse populations, including people with type 2 diabetes. People with type 1 diabetes, however, were excluded from these studies because of an increased risk of DKA, especially with SGLT2 inhibitors. Given the effect size in the accumulating outcome studies in other populations, the benefit/risk ratio is likely to be positive, in the absence of recent or recurrent DKA. Currently, several studies are reassessing the use of both classes of drugs for type 1 diabetes.

### Blood Pressure

Large RCTs in people without diabetes and Chinese people with type 2 diabetes have demonstrated that treatment of hypertension targeting a blood pressure <120/80 mmHg reduces cardiovascular events (318,319). Blood pressure targets should be personalized, with higher targets in the presence of, for example, orthostatic hypotension. If it can be safely attained, the on-treatment blood pressure goal is <130/80 mmHg, but a target of <120/80 mmHg is encouraged for those with higher cardiovascular or kidney disease risk (15).

ACE inhibitors, angiotensin receptor blockers, calcium antagonists, and thiazides are recommended first-line therapies, with a preference for RAAS inhibition in case of moderately elevated albuminuria. β-Blockers are generally contraindicated, as they may diminish symptoms of hypoglycemia, and should only be used when clearly indicated and with caution (15).

### Cholesterol

An observational study reported that lipid-lowering therapy is associated with a 22–44% reduction in the risk of CVD and death among individuals with type 1 diabetes without a prior history of CVD (320). Based on type 2 diabetes guidelines, statins should be considered for people aged over 40 years, and in those aged between 20 and 39 years when the 10-year cardiovascular risk estimated by one of the risk calculators suitable for people with type 1 diabetes exceeds 10% (119,321,322). Coronary artery calcium scores may be helpful for individuals who are at intermediate risk of atherosclerotic CVD, as a score of 0 substantially decreases the risk estimate. Coronary artery scores are not helpful for assessing the effect of statin therapy, as statins can increase the score by increasing plaque density and stabilization (323). The treatment goal is to aim for at least a 50% decrease from the initial LDL cholesterol level to a target of <1.8 mmol/L (<70 mg/dL) for primary prevention and <1.4 mmol/L (<55 mg/dL) for those with established CVD. Further information related to cholesterol lowering, for example secondary prevention, statin intolerance, and pregnancy, is available elsewhere (15).

### Aspirin

Aspirin is indicated for all people with type 1 diabetes and existing CVD but is not generally recommended for primary prevention in type 1 diabetes and is associated with an increased risk of gastrointestinal bleeding (316).

### Screening in Asymptomatic Individuals

Investigations for coronary artery disease should be considered in the presence of any of the following: signs or symptoms of cardiac or associated vascular disease: carotid bruits, transient ischemic attacks, stroke, claudication, or peripheral arterial disease or electrocardiographic abnormalities (e.g., Q waves) (15). However, routine screening for coronary artery disease is not recommended, as it does not improve outcomes as long as atherosclerotic CVD risk factors are treated.

### Heart Failure

Heart failure is becoming increasingly common in people with type 1 diabetes, especially women (324). NT-proBNP is recognized as a diagnostic and prognostic marker for heart failure, and its measurement may help identify those at risk (15). RAAS blockers and diuretics remain the preferred agents for early heart failure, but a cardiologist should be involved for those with more advanced disease. Given the improved outcomes seen in heart failure in those with type 2 diabetes and those without diabetes, people with heart failure and type 1 diabetes are likely to benefit from SGLT2 inhibitors. A decision to initiate treatment should be individualized, balancing the likely benefit against the 2.57- to 5.96-fold higher risk for DKA (226). If used, caution is required, with planned ketone monitoring, especially during intercurrent illness or surgical procedures, because of the risk of DKA, which is often euglycemic (228).

## SECTION 13: MANAGEMENT OF OBESITY

***Key Points***

- Overweight and obesity are at least as common in people with type 1 diabetes as in the general population.
- Additional contributing factors include increased food intake to prevent hypoglycemia and the effects of hyperinsulinemia.
- Treatment should include behavioral interventions, pharmacotherapy using second-generation obesity management medication, and, if indicated, bariatric surgery.

Contrary to the common perception that people with type 1 diabetes are lean, obesity rates in type 1 diabetes mirror those in the general population and warrant clinical attention, not least because of the substantially higher risk of CVD (325,326). In addition to the usual etiological factors, recurrent food intake to prevent or correct hypoglycemia and the unphysiological subcutaneous administration of insulin further

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contribute to weight gain in this population (327). Consequently, obesity management in type 1 diabetes presents a significant clinical challenge.

### Behavioral Modification

#### *Meal Planning*

Currently, there is insufficient evidence to support one specific meal planning approach for weight loss in individuals with type 1 diabetes. Nutrition education and individual preferences should be prioritized to ensure long-term sustainability. A 3-month pilot study in young adults found no significant difference in weight loss (mean 2.7 kg) among participants randomized to a hypocaloric low-carbohydrate diet, a hypocaloric moderate low-fat diet, or a Mediterranean diet (328). Additionally, a review of eight studies investigating low-carbohydrate diets in type 1 diabetes reported mixed outcomes regarding changes in BMI and total daily insulin requirements. The limited sample size in these studies precluded a valid meta-analysis (329).

Any meal planning strategy aimed at reducing energy intake in type 1 diabetes must demonstrate safety, particularly concerning the risks of hypoglycemia and hyperglycemia. Very-low-carbohydrate (ketogenic) diets raise ongoing concerns, including increased risks of hypoglycemia, diminished glycogen stores that may blunt the glucagon response, and the potential for relative insulin deficiency leading to DKA (329,330).

#### *Exercise*

As in the general population, there is limited research specifically examining weight loss through exercise in individuals with type 1 diabetes. Although exercise offers numerous health benefits, a meta-analysis of 24 studies found no consistent reduction in BMI associated with physical activity alone (331). However, regular exercise when combined with strategies such as reducing total daily insulin doses and avoiding excessive energy intake to treat hypoglycemia may aid with weight loss and blunt loss of lean body mass (102).

### Pharmacotherapy

#### *First-Generation Obesity Management Medications*

For individuals with diabetes, current guidelines recommend considering obesity medications for those with BMI >27 kg/m$^2$. In the U.S. six medications are approved for chronic weight management, with three approved for short-term use only (phentermine, phendimetrazine, and diethylpropion) (332). None of these are approved in Europe, and none have been studied in individuals with type 1 diabetes. All are rarely used today in this population.

Metformin and SGLT2 inhibitors can cause small weight reductions when used as adjunctive agents but should not be used as treatments for weight loss (Table 6).

#### *GLP-1 and Dual Receptor Agonists*

There are currently six GLP-1 or dual receptor agonists available, all of which are approved for the treatment of type 2 diabetes. Among these, liraglutide, semaglutide, and tirzepatide are also approved for the treatment of obesity. While the prescribing information for these medications explicitly states that they are not approved for diabetes management in type 1 diabetes, the labeling for their obesity indications does not mention type 1 diabetes. As such, when prescribed for obesity, these agents are not contraindicated in individuals with type 1 diabetes and may be considered for selected people under appropriate clinical supervision.

Retrospective observational studies have demonstrated the potential effectiveness of GLP-1 receptor agonists in individuals with type 1 diabetes. In one study with a matched control group, participants receiving treatment experienced a mean weight loss of 7.2 kg over 12 months, compared with a 1.0-kg weight gain in the control group (333). Additionally, there was a modest, nonsignificant improvement in $HbA_{1c}$ of 3 mmol/mol (0.3%), along with a statistically significant reduction in hypoglycemia as measured by CGM.

Another study reported a 10.1% reduction in body weight at 8 months among individuals with type 1 diabetes treated with tirzepatide (223). However, the use of these agents in this population requires support for insulin dose adjustments in response to the effects of incretin therapy, whether individuals are using MDI or insulin pump therapy, including AID systems (334). It is also important to consider the need for insulin dose adjustments in the context of weight loss. When initiating GLP-1 receptor agonist therapy, delayed gastric emptying, typically a short-term effect, can increase the risk of immediate postprandial hypoglycemia, particularly during the early phase of treatment or in the presence of nausea or vomiting.

### Bariatric Surgery

People with a BMI >35 kg/m$^2$ accompanied by weight-related complications, or a BMI >40 kg/m$^2$, meet the criteria for bariatric surgery (335). To date, bariatric surgery remains the most effective long-term treatment for severe obesity, although it carries the highest risk among available interventions; these include both short-term surgical risks and longer-term medical risks.

As with the use of obesity management medications, the evidence base for bariatric surgery is still emerging in individuals with type 1 diabetes. A systematic review and meta-analysis involving over 600 individuals with type 1 diabetes reported substantial benefits after just under 3 years, including a reduction in mean BMI from 42.6 kg/m$^2$ to 29 kg/m$^2$, decreased insulin requirements, and improved $HbA_{1c}$ levels (336).

However, important clinical questions remain regarding which individuals with type 1 diabetes and severe obesity are most likely to benefit from surgical intervention, and which type of procedure should be recommended. Hypoglycemia is the most frequently reported complication following bariatric surgery in this population, with an incidence exceeding 50% (337,338). Furthermore, there have been several cases of iatrogenic DKA when insulin is stopped after surgery, in line with guidance for type 2 diabetes.

## SECTION 14: OLDER PEOPLE

#### *Key Points*

- Patient safety, particularly avoidance of hypoglycemia, is a key priority for older individuals.
- Glycemic treatment approaches and targets should be based on functional and cognitive status, available care partner support, history of hypoglycemia and impaired awareness, fear of hypoglycemia and hyperglycemia, and life expectancy, rather than chronological age.
- The use of advanced technologies in older individuals living independently, including those with mild cognitive impairment, is effective and safe and

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should not be discontinued or a priori excluded solely based on age.
- Simplification of insulin management may be needed to maintain patient safety and prevent diabetes symptoms. In some cases, this may require insulin to be administered by a caregiver or the older person to be supervised while self-dosing.

The population of older adults with type 1 diabetes is growing because of the increasing incidence of type 1 diabetes, more individuals being diagnosed in adulthood, and rising life expectancy (339,340). This group of older adults is highly heterogeneous. Many older adults remain healthy and should be managed in a similar way to younger individuals. However, as comorbidities and frailty develop, reassessment of diabetes management, including potential modifications to insulin therapy, is essential.

Glycemic treatment strategies and targets should be personalized based on functional and cognitive status, availability of care partner support, history of hypoglycemia and IAH, fear of both hypoglycemia and hyperglycemia, and life expectancy, rather than being based on chronological age. Patient safety is paramount. Given the heightened vulnerability to hypoglycemia, older adults with type 1 diabetes may require adjusted glucose targets to reduce the risk of hypoglycemia (18). If insulin administration becomes challenging, simplification of insulin regimens may be appropriate, especially in those with frailty or significant functional or cognitive decline (18).

Advanced diabetes technologies can be highly beneficial in older adults and should not be discontinued or excluded solely based on age (170,341,342). CGM reduces hypoglycemia without increasing hyperglycemia in both healthy older adults and those with mild cognitive impairment (170,341). However, older individuals may be less familiar with and more apprehensive about new technologies. Clear explanations and training, tailored to both the individual and their caregivers, are essential. Training typically takes longer in older adults than in younger individuals (343), but, with adequate education and support, older adults can use these tools effectively, improve glycemic levels, and feel safer.

Alarm settings should be personalized to meet the needs and preferences of the individual, and data sharing with a supportive caregiver can be especially helpful as health declines (344). When selecting new devices, factors such as usability (affected by dexterity, vision, hearing, and cognition) and cost should be considered.

Similar to CGM, AID systems reduce hypoglycemia and improve TIR in older adults who are healthy or who have mild cognitive impairment (345–348). A personalized approach is often needed during both initial training and ongoing use. The potential role of a caregiver should be evaluated, as they may also require training, although the autonomy of the older adult should be preserved as much as possible.

Other technologies, such as mobile apps for reminders and activity tracking, or digital home assistants, have not been extensively studied in this population but may support independence in those with specific impairments. Given the diversity and evolving health status of older adults with type 1 diabetes, and the growing availability of advanced technologies, treatment strategies including the use of newer devices should be regularly reevaluated as health, living situations, support systems, and device usability change.

When someone moves into a residential care home, insulin should not be withheld but, where possible and safe, the insulin regimen should be simplified and glucose targets relaxed to avoid the risk of hypoglycemia (18). Appropriate staff training and clear protocols that include written insulin administration plans and hypoglycemia management protocols are essential.

## SECTION 15: PREGNANCY INCLUDING PRECONCEPTION AND POSTNATAL CARE

***Key Points***

- Health care professionals should discuss pregnancy prior to conception, including the effects of pregnancy on diabetes and vice versa, glycemic targets, and a review of medications.
- All pregnant individuals with type 1 diabetes should be referred to a clinic with expertise in the management of diabetes in pregnancy if available.
- Glycemic targets are more stringent during pregnancy to avoid adverse pregnancy outcomes. These goals should be discussed and reviewed with the pregnant individual.
- Insulin requirements fluctuate significantly during pregnancy and postpartum and with breastfeeding. Frequent glucose monitoring is required to guide dose adjustments.
- Automated insulin delivery (AID) systems should be made available prior to, during, and after pregnancy, but health care professionals should be aware that not all AID systems are approved for use in pregnancy.

### Preconception Planning

Effective pregnancy management in type 1 diabetes begins before conception, as planned pregnancies are associated with better outcomes for both the mother and the child. Glycemic levels should be optimized before conception, as this reduces the risk of congenital anomalies, miscarriage, and other adverse pregnancy outcomes (349,350). Ideally, women should maintain a near-normal $HbA_{1c}$, preferably <48 mmol/mol (6.5%), at least 3 months prior to conception, as this lowers the risk of adverse pregnancy outcomes related to hyperglycemia during embryogenesis.

All medications should be reviewed and any associated with fetal harm should be removed. RAAS inhibitors are contraindicated in pregnancy because of well-established fetal risks and should be discontinued before conception and replaced with pregnancy-safe agents such as nifedipine or labetalol (19). Statins, which are commonly taken by people with type 1 diabetes, should not be used during pregnancy.

Education should be provided on the need for more intensive blood glucose monitoring and insulin dose adjustments and the importance of maintaining a balanced diet. Folic acid supplementation (typically 5 mg daily) is strongly recommended before conception and during early pregnancy to reduce the risk of neural tube defects, which is elevated in women with diabetes.

Managing diabetes-related complications prior to pregnancy, such as hypertension, nephropathy, and retinopathy, is essential. Optimizing blood pressure

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and glucose levels, along with comprehensive eye examinations, can help prevent the progression of these conditions during pregnancy. Until optimal glucose levels are reached and comorbidities are well-managed, effective contraception should be used. The choice of contraceptive method should be both safe and reliable, tailored to the individual's medical history and personal preferences (19).

### During Pregnancy

When possible, individuals should be referred early to a clinic with expertise in the management of diabetes in pregnancy. Pregnant individuals with type 1 diabetes require more intensive and frequent monitoring than is typically available in standard diabetes care. Diabetes in pregnancy is best managed by a multidisciplinary team, including a diabetologist or endocrinologist, obstetrician, dietitian, diabetes nurse or educator, and diabetes midwife (19). A detailed discussion of pregnancy management in individuals with type 1 diabetes is beyond the scope of this report and so only a brief description is given here (19).

Hyperglycemia during pregnancy increases the risk of complications for both the pregnant individual and the developing fetus and may also impact long-term child development (349,350). Therefore, individuals with type 1 diabetes should be supported in achieving optimal glycemic levels.

CGM use has been approved for use in pregnancy in both the U.S. and Europe, depending on the device. The CONCEPTT trial demonstrated that CGM use during pregnancy was associated with improved outcomes (351). As such, CGM should be encouraged during pregnancy, with the understanding that BGM remains necessary in situations where CGM accuracy may be compromised. Importantly, CGM target glucose ranges during pregnancy differ from standard recommendations, with TIR defined as 3.5–7.8 mmol/L (63–140 mg/dL) (Fig. 4) (352,353). Consequently, CGM reports should be interpreted using these adjusted thresholds, and alarm settings may need to be modified to alert users earlier to hyperglycemia while avoiding unnecessary alarms for appropriately lower glucose levels. Where CGM is unavailable, capillary BGM targets are shown in Table 4.

Hypoglycemia remains the primary barrier to optimizing glycemic levels during pregnancy. It is particularly common in the first half of pregnancy, partly due to IAH and pregnancy-related nausea and vomiting (354). Conversely, pregnant individuals with type 1 diabetes are at risk for DKA at lower blood glucose levels than in the nonpregnant state and should receive education on DKA prevention and detection (355).

AID systems are emerging as standard of care for managing type 1 diabetes during pregnancy. Randomized clinical trials have shown that AID systems can improve glycemic levels and quality of life during pregnancy (356–362). However, these studies have not demonstrated significant improvements in fetal outcomes, such as neonatal birth weight, hypoglycemia rates, or perinatal mortality, probably because they were not sufficiently powered to detect differences in these outcomes.

Not all AID systems are approved for use in pregnancy, and regulatory approval varies between countries. ADA recognizes that AID systems may help improve glycemic management during pregnancy in selected individuals with type 1 diabetes. Accordingly AID systems that do not incorporate pregnancy-specific glucose targets or algorithms may be considered when used with assistive techniques and support from experienced multidisciplinary teams (19).

The Endocrine Society and European Society of Endocrinology recommend the use of AID systems where available, provided there is local expertise to support their implementation and management (363). In contrast, NICE explicitly recommends pregnancy-specific AID systems for people with type 1 diabetes who are pregnant or planning pregnancy, with training and support delivered by a specialist multidisciplinary team (364).

The UK National Pregnancy in Diabetes Audit has recently reported that 53% of individuals using pregnancy-specific AID systems had an $HbA_{1c}$ below 43 mmol/mol (6.1%), compared with 36% using an AID system without a pregnancy-specific algorithm and 37% using MDI (365). Use of pregnancy-specific AID systems was also associated with lower rates of preterm birth, large-for-gestational-age infants, and serious adverse outcomes, with comparable rates of neonatal unit admission. Rates of major congenital anomalies, stillbirth, and neonatal death among those using pregnancy-specific AID systems were the lowest recorded since national data collection began.

Further research is needed to evaluate the efficacy and safety of the various AID systems currently on the market for use during pregnancy.

### Postpartum Care

Postpartum care for individuals with type 1 diabetes is a critical aspect of long-term health management and preparation for future pregnancies. Following delivery, hormonal shifts and physiological changes often lead to enhanced insulin sensitivity, resulting in a marked reduction in insulin requirements. During this period, factors such as breastfeeding, irregular sleep, and inconsistent eating patterns can further elevate the risk of hypoglycemia, making careful insulin dose adjustments essential (366,367). Close monitoring of glucose levels is vital to prevent hypoglycemic episodes and maintain stable glycemic levels. AID systems may improve glycemic levels during the peripartum and postpartum periods (359,360).

Breastfeeding is strongly encouraged due to its benefits for both mother and child. However, it can influence insulin needs, often leading to reduced requirements (366). Individuals should receive guidance on balancing insulin therapy with breastfeeding and the importance of maintaining optimal glycemic levels to support effective lactation. Continued education on nutrition and medication taking is essential to support stable glucose levels during the postpartum period.

Finally, this phase offers an opportunity to revisit long-term diabetes management goals and prepare for future pregnancies if desired. Counseling on contraceptive options and timing of subsequent pregnancies should be provided, emphasizing the importance of preconception care to achieve optimal glycemic levels prior to conception.

## SECTION 16: IN-HOSPITAL MANAGEMENT

***Key Points***

- People with type 1 diabetes are at increased risk of developing diabetic ketoacidosis in hospital.
- A target glucose range of 7.8–10.0 mmol/L (140–180 mg/dL) should be

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used for most noncritically and critically ill patients. A glucose goal of 5.6–10.0 mmol/L (100–180 mg/dL) may be used in noncritically ill individuals if this can be attained without hypoglycemia.
- Adopting diabetes technology in hospitals may benefit individuals with diabetes by helping overcome the unmet need for better inpatient glycemic management and alleviating the workload of clinical staff. Where feasible, noncritically ill adults with type 1 diabetes should be allowed to use diabetes technology with appropriate support.

It is important that the hospital teams recognize the key differences between type 1 diabetes and type 2 diabetes because of the high risk of DKA if insulin is withheld in people with type 1 diabetes (22). Therefore, inpatients with type 1 diabetes should be clearly identified to avoid common errors, such as omission of mealtime insulin or withholding of basal insulin for procedures or surgery. People with type 1 diabetes, particularly those with concomitant chronic kidney disease, are at higher risk of hypoglycemia, which should be avoided by careful basal insulin dosing, mealtime insulin bolusing based on carbohydrate matching, and correction dosing for hyperglycemia (20).

There have been no large RCTs specifically assessing glycemic targets for inpatients with type 1 diabetes. Therefore, we recommend following type 2 diabetes guidelines, which recommend target glucose ranges of 7.8–10.0 mmol/L (140–180 mg/dL) for the majority of noncritically and critically ill patients (20). A glucose goal of 5.6–10.0 mmol/L (100–180 mg/dL) may be used in noncritically ill individuals if it can be attained without hypoglycemia, for example in individuals continuing to use their home AID system (20).

Data on use of diabetes technologies, including CGM and AID, are still limited in the inpatient setting (368). One of the reasons is lack of formal approval of those devices for inpatient use by the U.S. FDA (369). Adopting diabetes technology in hospitals may potentially benefit individuals with diabetes by helping overcome the unmet need for better inpatient glycemic management while alleviating the workload of clinical staff (368). Evidence supporting CGM effectiveness and safety in noncritically ill inpatients is growing, including in those on hemodialysis, and after abdominal surgery and solid organ transplantation (370–376). Hospital-wide CGM policies with electronic health record integration have been used successfully, with good satisfaction reported by nurses and adults with diabetes (377). The evidence concerning effective usage of AID systems in hospitalized individuals, however, is quite limited (378). Although randomized trials are lacking, the benefits of AID use in hospitalized individuals with type 1 diabetes may include improved glycemic outcomes, reduced staff workload, and increased patient satisfaction (369). However, the use of AID should be withheld in people hospitalized for intercurrent illness and/or receiving drugs (e.g., steroids) that significantly impair glucose homeostasis, as well as in people who are no longer capable of managing AID, unless appropriately trained staff are available for support.

Noncritically ill adults with type 1 diabetes using diabetes devices (CGM, insulin pumps, AID systems) should be allowed to use them during outpatient procedures or in inpatient settings when proper supervision is available and the individuals/caregivers have clear mentation, previous training, and education and are capable of managing the device(s) (379–381). Institutions should have clear guidelines and protocols in place to manage inpatient type 1 diabetes safely, including enabling selected adults who can monitor their glucose and self-administer insulin safely to continue managing their diabetes during hospitalization.

If a dedicated inpatient diabetes service is available, it should be consulted for glycemic management, DSMES and discharge planning (20).

## CONCLUSION

The 2021 consensus report significantly influenced the clinical management of type 1 diabetes in adults, becoming a landmark reference for health care professionals and informing national and international diabetes policy (4,5). It raised awareness of adult-onset type 1 diabetes, endorsed personalized glycemic targets and promoted the adoption of CGM and TIR metrics. Importantly, it underscored the emotional burden of living with diabetes and the need to embed psychosocial care into routine clinical practice. This updated report reflects the continued evolution of type 1 diabetes management, incorporating advances in diagnosis, therapy, and technology. Yet, the writing group acknowledges persistent and substantial evidence gaps across prevention, diagnosis, and treatment. People with type 1 diabetes deserve high-quality research to guide their care. We also recognize the ongoing disparities in access to treatment and advocate strongly for equitable, person-centered services to ensure that all individuals with type 1 diabetes receive the care they need and deserve.

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