



## 7. Diabetes Technology: *Standards of Medical Care in Diabetes—2021*

American Diabetes Association

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The American Diabetes Association (ADA) “Standards of Medical Care in Diabetes” includes the ADA’s current clinical practice recommendations and is intended to provide the components of diabetes care, general treatment goals and guidelines, and tools to evaluate quality of care. Members of the ADA Professional Practice Committee, a multidisciplinary expert committee (<https://doi.org/10.2337/dc21-SPPC>), are responsible for updating the Standards of Care annually, or more frequently as warranted. For a detailed description of ADA standards, statements, and reports, as well as the evidence-grading system for ADA’s clinical practice recommendations, please refer to the Standards of Care Introduction (<https://doi.org/10.2337/dc21-SINT>). Readers who wish to comment on the Standards of Care are invited to do so at [professional.diabetes.org/SOC](https://professional.diabetes.org/SOC).

Diabetes technology is the term used to describe the hardware, devices, and software that people with diabetes use to help manage their condition, from lifestyle to blood glucose levels. Historically, diabetes technology has been divided into two main categories: insulin administered by syringe, pen, or pump, and blood glucose monitoring as assessed by meter or continuous glucose monitor. More recently, diabetes technology has expanded to include hybrid devices that both monitor glucose and deliver insulin, some automatically, as well as software that serves as a medical device, providing diabetes self-management support. Diabetes technology, when coupled with education and follow-up, can improve the lives and health of people with diabetes; however, the complexity and rapid change of the diabetes technology landscape can also be a barrier to patient and provider implementation.

### Recommendation

**7.1** Use of technology should be individualized based on a patient’s needs, desires, skill level, and availability of devices. **E**

Technology is rapidly changing, but there is no “one-size-fits-all” approach to technology use in people with diabetes. Insurance coverage can lag behind device availability, patient interest in devices and willingness to change can vary, and providers may have trouble keeping up with newly released technology. Not-for-profit websites can help providers and patients make decisions as to the initial choice of devices. Other sources, including health care providers and device manufacturers, can help people troubleshoot when difficulties arise.

### SELF-MONITORING OF BLOOD GLUCOSE

#### Recommendations

**7.2** People who are on insulin using self-monitoring of blood glucose should be encouraged to test when appropriate based on their insulin regimen. This may

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include testing when fasting, prior to meals and snacks, at bedtime, prior to exercise, when low blood glucose is suspected, after treating low blood glucose until they are normoglycemic, and prior to and while performing critical tasks such as driving. **B**

**7.3** Providers should be aware of the differences in accuracy among glucose meters—only U.S. Food and Drug Administration–approved meters with proven accuracy should be used, with unexpired strips, purchased from a pharmacy or licensed distributor. **E**

**7.4** When prescribed as part of a diabetes self-management education and support program, self-monitoring of blood glucose may help to guide treatment decisions and/or self-management for patients taking less frequent insulin injections. **B**

**7.5** Although self-monitoring of blood glucose in patients on noninsulin therapies has not consistently shown clinically significant reductions in A1C, it may be helpful when altering diet, physical activity, and/or medications (particularly medications that can cause hypoglycemia) in conjunction with a treatment adjustment program. **E**

**7.6** When prescribing self-monitoring of blood glucose, ensure that patients receive ongoing instruction and regular evaluation of technique, results, and their ability to use data, including uploading/sharing data (if applicable), from self-monitoring of blood glucose devices to adjust therapy. **E**

**7.7** Health care providers should be aware of medications and other factors, such as high-dose vitamin C and hypoxemia, that can interfere with glucose meter accuracy and provide clinical management as indicated. **E**

Major clinical trials of insulin-treated patients have included self-monitoring of blood glucose (SMBG) as part of multifactorial interventions to demonstrate the benefit of intensive glycemic control on diabetes complications (1). SMBG is thus an integral component of effective

therapy of patients taking insulin. In recent years, continuous glucose monitoring (CGM) has emerged as a method for the assessment of glucose levels (discussed below). Glucose monitoring allows patients to evaluate their individual response to therapy and assess whether glycemic targets are being safely achieved. Integrating results into diabetes management can be a useful tool for guiding medical nutrition therapy and physical activity, preventing hypoglycemia, or adjusting medications (particularly prandial insulin doses). The patient's specific needs and goals should dictate SMBG frequency and timing or the consideration of CGM use.

#### Meter Standards

Glucose meters meeting U.S. Food and Drug Administration (FDA) guidance for meter accuracy provide the most reliable data for diabetes management. There are several current standards for accuracy of blood glucose monitors, but the two most used are those of the International Organization for Standardization (ISO) (ISO 15197:2013) and the FDA. The current ISO and FDA standards are compared in **Table 7.1**. In Europe, currently marketed monitors must meet current ISO standards. In the U.S., currently marketed monitors must meet the standard under which they were approved, which may not be the current standard. Moreover, the monitoring of current accuracy is left to the manufacturer and not routinely checked by an independent source.

Patients assume their glucose monitor is accurate because it is FDA cleared, but often that is not the case. There is substantial variation in the accuracy of widely used blood glucose monitoring systems (2,3). The Diabetes Technology Society Blood Glucose Monitoring System Surveillance Program provides information on the performance of devices used for SMBG (<https://diabetestechnology.org/surveillance>). In one analysis, only 6 of the top 18 glucose meters met the accuracy standard (4).

There are single-meter studies in which benefits have been found with individual meter systems, but few that compare meters in a head-to-head manner. Certain meter system characteristics, such as the use of lancing devices that are less painful (5) and the ability to reapply blood to a strip with an insufficient initial sample, may also be beneficial to patients (6) and may make SMBG less burdensome for patients to perform.

#### Counterfeit Strips

Patients should be advised against purchasing or reselling preowned or second-hand test strips, as these may give incorrect results. Only unopened and unexpired vials of glucose test strips should be used to ensure SMBG accuracy.

#### Optimizing SMBG Monitor Use

SMBG accuracy is dependent on the instrument and user, so it is important to evaluate each patient's monitoring technique, both initially and at regular intervals thereafter. Optimal use of SMBG requires proper review and interpretation of the data, by both the patient and the provider, to ensure that data are used in an effective and timely manner. In patients with type 1 diabetes, there is a correlation between greater SMBG frequency and lower A1C (7). Among patients who check their blood glucose at least once daily, many report taking no action when results are high or low (8). Patients should be taught how to use SMBG data to adjust food intake, exercise, or pharmacologic therapy to achieve specific goals. Some meters now provide advice to the user in real time, when monitoring glucose levels (9), while others can be used as a part of integrated health platforms (10).

The ongoing need for and frequency of SMBG should be reevaluated at each routine visit to avoid overuse, particularly if SMBG is not being used effectively for self-management (8,11,12).

#### Patients on Intensive Insulin Regimens

SMBG is especially important for insulin-treated patients to monitor for and prevent hypoglycemia and hyperglycemia. Most patients using intensive insulin regimens (multiple daily injections or insulin pump therapy) should be encouraged to assess glucose levels using SMBG (and/or CGM) prior to meals and snacks, at bedtime, occasionally postprandially, prior to exercise, when they suspect low blood glucose, after treating low blood glucose until they are normoglycemic, and prior to and while performing critical tasks such as driving. For many patients using SMBG, this will require checking up to 6–10 times daily, although individual needs may vary. A database study of almost 27,000 children and adolescents with type 1 diabetes showed that, after adjustment for multiple confounders, increased daily frequency of SMBG was significantly associated with lower A1C

**Table 7.1—Comparison of ISO 15197:2013 and FDA blood glucose meter accuracy standards**

Setting	FDA (206,207)	ISO 15197:2013 (208)
Home use	95% within 15% for all BG in the usable BG range† 99% within 20% for all BG in the usable BG range†	95% within 15% for BG ≥100 mg/dL 95% within 15 mg/dL for BG <100 mg/dL 99% in A or B region of consensus error grid‡
Hospital use	95% within 12% for BG ≥75 mg/dL 95% within 12 mg/dL for BG <75 mg/dL 98% within 15% for BG ≥75 mg/dL 98% within 15 mg/dL for BG <75 mg/dL	

BG, blood glucose; FDA, U.S. Food and Drug Administration; ISO, International Organization for Standardization. To convert mg/dL to mmol/L, see <http://endmemo.com/medical/unitconvert/Glucose.php>. †The range of blood glucose values for which the meter has been proven accurate and will provide readings (other than low, high, or error). ‡Values outside of the “clinically acceptable” A and B regions are considered “outlier” readings and may be dangerous to use for therapeutic decisions (209).

(−0.2% per additional check per day) and with fewer acute complications (13).

#### Patients Using Basal Insulin and/or Oral Agents

The evidence is insufficient regarding when to prescribe SMBG and how often monitoring is needed for insulin-treated patients who do not use intensive insulin regimens, such as those with type 2 diabetes using basal insulin with or without oral agents. However, for patients using basal insulin, assessing fasting glucose with SMBG to inform dose adjustments to achieve blood glucose targets results in lower A1C (14,15).

In people with type 2 diabetes not using insulin, routine glucose monitoring may be of limited additional clinical benefit. By itself, even when combined with education, it has showed limited improvement in outcomes (16–19). However, for some individuals, glucose monitoring can provide insight into the impact of diet, physical activity, and medication management on glucose levels. Glucose monitoring may also be useful in assessing hypoglycemia, glucose levels during intercurrent illness, or discrepancies between measured A1C and glucose levels when there is concern an A1C result may not be reliable in specific individuals. It may be useful when coupled with a treatment adjustment program. In a year-long study of insulin-naïve patients with suboptimal initial glycemic stability, a group trained in structured SMBG (a paper tool was used at least quarterly to collect and interpret seven-point SMBG profiles taken on 3 consecutive days) reduced their A1C by 0.3% more than the control group (20). A trial of once-daily SMBG that included enhanced patient feedback through messaging found no clinically or statistically significant change in A1C at 1 year (19). Meta-analyses have suggested that

SMBG can reduce A1C by 0.25–0.3% at 6 months (21–23), but the effect was attenuated at 12 months in one analysis (21). Reductions in A1C were greater (−0.3%) in trials where structured SMBG data were used to adjust medications, but A1C was not changed significantly without such structured diabetes therapy adjustment (23). A key consideration is that performing SMBG alone does not lower blood glucose levels. To be useful, the information must be integrated into clinical and self-management plans.

#### Glucose Meter Inaccuracy

Although many meters function well under a variety of circumstances, providers and people with diabetes need to be aware of factors that can impair meter accuracy. A meter reading that seems discordant with clinical reality needs to be retested or tested in a laboratory. Providers in intensive care unit settings need to be particularly aware of the potential for abnormal meter readings, and laboratory-based values should be used if there is any doubt. Some meters give error messages if meter readings are likely to be false (24).

**Oxygen.** Currently available glucose monitors utilize an enzymatic reaction linked to an electrochemical reaction, either glucose oxidase or glucose dehydrogenase (25). Glucose oxidase monitors are sensitive to the oxygen available and should only be used with capillary blood in patients with normal oxygen saturation. Higher oxygen tensions (i.e., arterial blood or oxygen therapy) may result in false low glucose readings, and low oxygen tensions (i.e., high altitude, hypoxia, or venous blood readings) may lead to false high glucose readings. Glucose dehydrogenase-based monitors are not sensitive to oxygen.

**Temperature.** Because the reaction is sensitive to temperature, all monitors have an acceptable temperature range (25). Most will show an error if the temperature is unacceptable, but a few will provide a

reading and a message indicating that the value may be incorrect.

**Interfering Substances.** There are a few physiologic and pharmacologic factors that interfere with glucose readings. Most interfere only with glucose oxidase systems (25). They are listed in **Table 7.2**.

**Table 7.2—Interfering substances for glucose readings**

Glucose oxidase monitors
Uric acid
Galactose
Xylose
Acetaminophen
L-DOPA
Ascorbic acid
Glucose dehydrogenase monitors
Icodextrin (used in peritoneal dialysis)

## CONTINUOUS GLUCOSE MONITORING DEVICES

See **Table 7.3** for definitions of types of CGM devices.

#### Recommendations

**7.8** When prescribing continuous glucose monitoring (CGM) devices, robust diabetes education, training, and support are required for optimal CGM device implementation and ongoing use. People using CGM devices need to have the ability to perform self-monitoring of blood glucose in order to calibrate their monitor and/or verify readings if discordant from their symptoms. **B**

**7.9** When used properly, real-time continuous glucose monitors in conjunction with multiple daily injections and continuous subcutaneous insulin infusion **A** and other forms of insulin therapy **C** are a useful tool to lower and/or maintain A1C levels and/or reduce

hypoglycemia in adults and youth with diabetes.

- 7.10** When used properly, intermittently scanned continuous glucose monitors in conjunction with multiple daily injections and continuous subcutaneous insulin infusion **B** and other forms of insulin therapy **C** can be useful and may lower A1C levels and/or reduce hypoglycemia in adults and youth with diabetes to replace self-monitoring of blood glucose.
- 7.11** In patients on multiple daily injections and continuous subcutaneous insulin infusion, real-time continuous glucose monitoring (CGM) devices should be used as close to daily as possible for maximal benefit. **A** Intermittently scanned CGM devices should be scanned frequently, at a minimum once every 8 h.
- 7.12** When used as an adjunct to pre- and postprandial self-monitoring of blood glucose, continuous glucose monitoring can help to achieve A1C targets in diabetes and pregnancy. **B**
- 7.13** Use of professional continuous glucose monitoring (CGM) and/or intermittent real-time or intermittently scanned CGM can be helpful in identifying and correcting patterns of hyper- and hypoglycemia and improving A1C levels in people with diabetes on noninsulin as well as basal insulin regimens. **C**
- 7.14** Skin reactions, either due to irritation or allergy, should be assessed and addressed to aid in successful use of devices. **E**
- 7.15** People who have been using continuous glucose monitors should have continued access across third-party payers. **E**

CGM measures interstitial glucose (which correlates well with plasma glucose, although at times can lag if glucose levels are rising or falling rapidly). There are two basic types of CGM devices: those that are owned by the user, unblinded, and intended for frequent/continuous use (real-time [rt]CGM and intermittently scanned [is]CGM) and those that are owned and applied in/by the clinic, which provide data that is blinded or unblinded for a discrete period of time (professional CGM). **Table 7.3** provides the definitions for the types of CGM devices. For devices that provide patients unblinded data, most of the published randomized controlled trials (RCTs) have been performed using rtCGM devices that have alarms and alerts. The RCT results have largely been positive, in terms of reducing either A1C levels and/or episodes of hypoglycemia, as long as participants regularly wear the devices (26–29). These devices provide glucose readings continuously to a smartphone or reader that can be viewed by the patient and/or a caregiver. It is difficult to determine how much the need to swipe a device to obtain a result, combined with a lack of alarms and alerts, matters in terms of outcomes, although results from these devices (isCGM) have not shown consistent improvements in glycemic outcomes (30). However, data from longitudinal trials (without a control group for comparison) show improvement in A1C levels (31). There is one small study in patients at risk for hypoglycemia that compared rtCGM with isCGM (32). The study showed improvement in time spent in hypoglycemia with rtCGM compared with isCGM. The newest version of the isCGM system has an optional alert for a high or low glucose value (without the capacity for providing predictive alerts), but it still requires that the device be swiped to reveal the glucose level and trend arrows, and RCT data are lacking in terms of

added benefit. This device (FreeStyle Libre 2) and one rtCGM (Dexcom G6) have both been designated as integrated continuous glucose monitoring (iCGM) devices (<https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpdc/classification.cfm?id=682>). This is a higher standard, set by the FDA, so these devices can be reliably integrated with other digitally connected devices, including automated insulin dosing systems.

Some real-time systems require calibration by the user, which varies in frequency depending on the device. Additionally, for some CGM systems, the FDA suggests SMBG for making treatment decisions. Devices that require SMBG confirmation are called “adjunctive,” while those that do not are called “nonadjunctive.” An RCT of 226 adults suggested that a CGM device could be used safely and effectively without regular confirmatory SMBG in patients with well-controlled type 1 diabetes at low risk of severe hypoglycemia (33). Two CGM devices are approved by the FDA for making treatment decisions without SMBG calibration or confirmation (34,35). For patients with type 1 diabetes using rtCGM, an important predictor of A1C lowering for all age-groups was frequency of sensor use (26). In this study, overall use was highest in those aged  $\geq 25$  years (who had the most improvement in A1C) and lower in younger age-groups.

The abundance of data provided by CGM offers opportunities to analyze patient data more granularly than was previously possible, providing additional information to aid in achieving glycemic targets. A variety of metrics have been proposed (27) and are discussed in Section 6 “Glycemic Targets” (<https://doi.org/10.2337/dc21-S006>). CGM is essential for creating the ambulatory glucose profile (AGP) and providing data on time in range, percentage of time spent above and below range, and variability

**Table 7.3—Continuous glucose monitoring (CGM) devices**

Type of CGM	Description
Real-time CGM (rtCGM)	CGM systems that measure and display glucose levels continuously
Intermittently scanned CGM (isCGM)	CGM systems that measure glucose levels continuously but only display glucose values when swiped by a reader or a smartphone
Professional CGM	CGM devices that are placed on the patient in the provider’s office (or with remote instruction) and worn for a discrete period of time (generally 7–14 days). Data may be blinded or visible to the person wearing the device. The data are used to assess glycemic patterns and trends. These devices are not fully owned by the patient—they are a clinic-based device, as opposed to the patient-owned rtCGM/isCGM devices.

(36). Access to CGM devices should be considered from the outset of the diagnosis of diabetes that requires insulin management (37,38). This allows for close tracking of glucose levels with adjustments of insulin dosing and lifestyle modifications and removes the burden of frequent SMBG monitoring. Interruption of access to CGM is associated with a worsening of outcomes (39); therefore, it is important for individuals on CGM to have consistent access to the devices.

### Education and Training

In general, no device used in diabetes management works optimally without education, training, and follow-up. Device companies offer online tutorials and training videos as well as written material on their use. Patients vary in terms of comfort level with technology, and some prefer in-person training and support. Programs that involve training and support have been shown to improve outcomes in both adults and children using isCGM (40–42). Individuals using CGM should also be trained on how to use SMBG, for use with devices that require calibration, for testing if CGM values seem incongruent with the patient's sense of their glucose levels, and if the CGM device fails or is not available.

### Real-time CGM Device Use in Adults and Children With Diabetes

Data exist to support the use of real-time CGM in adults and children, both those on multiple daily injections (MDI) and those on continuous subcutaneous insulin infusion (CSII). This is true in studies both in people with type 1 diabetes and those with type 2 diabetes, although data in individuals with type 2 diabetes is primarily in adults.

In terms of RCTs in people with type 1 diabetes, there are four studies in adults with A1C as the primary outcome (28,29,43–45), three studies in adults with hypoglycemia as the primary outcome (46–48), four studies in adults and children with A1C as the primary outcome (26,49–51), and three studies in adults and children with hypoglycemia as a primary outcome (52–54).

#### Primary Outcome: A1C Reduction—Adults

In general, A1C reduction was shown in studies where the baseline A1C was higher. In two larger studies in adults with type 1 diabetes that assessed the

benefit of rtCGM in patients on MDI, there were significant reductions in A1C:  $-0.6\%$  in one (28,43) and  $-0.43\%$  in the other (29). No reduction in A1C was seen in a small study performed in underserved, less well-educated adults with type 1 diabetes (44). In the adult subset of the JDRF CGM study, there was a significant reduction in A1C of  $-0.53\%$  (55) in patients who were primarily treated with insulin pump therapy. Better adherence in wearing the rtCGM device resulted in a greater likelihood of an improvement in glycemic control (26,45).

#### Primary Outcome: Hypoglycemia—Adults

In studies in adults where reduction in episodes of hypoglycemia was the primary end point, significant reductions were seen in individuals with type 1 diabetes on MDI or CSII (46–48). In one study in patients who were at higher risk for episodes of hypoglycemia (48), there was a reduction in rates of all levels of hypoglycemia (see Section 6 “Glycemic Targets,” <https://doi.org/10.2337/dc21-S006>, for hypoglycemia definitions). rtCGM may be particularly useful in insulin-treated patients with hypoglycemia unawareness and/or frequent hypoglycemic episodes, although studies have not been powered to show consistent reductions in severe (level 3) hypoglycemia (26,49,50).

#### Impact on Glycemic Control—Children

When data from adult and pediatric participants are analyzed together, rtCGM use in RCTs has been associated with reduction in A1C levels (49–51). Yet, in the JDRF CGM trial, when youth were analyzed by age-group (8- to 14-year-olds and 15- to 24-year-olds), no change in A1C was seen, likely due to poor rtCGM adherence (26). Indeed, in a secondary analysis of that RCT's data in both pediatric cohorts, those who used the sensor  $\geq 6$  days/week had an improvement in their glycemic control (56). One critical component to success with CGM is near-daily wearing of the device (49,55, 57–59). One RCT showed no improvement in glycemic outcomes in children aged 4–10 years of age, regardless of how often it was worn (60).

Though data from small observational studies demonstrate that rtCGM can be worn by patients  $< 8$  years old and the use of rtCGM provides insight to glycemic patterns (61,62), an RCT in children aged 4–9 years did not demonstrate improvements

in glycemic control following 6 months of rtCGM use (60). However, observational feasibility studies of toddlers demonstrated a high degree of parental satisfaction and sustained use of the devices despite the inability to change the degree of glycemic control attained (63).

Registry data have also shown an association between rtCGM use and lower A1C levels (55,64), even when limiting assessment of rtCGM use to participants on injection therapy (64).

#### Impact on Hypoglycemia—Children

There are no studies solely including pediatric patients that assess rates of hypoglycemia as the primary outcome. Some of the studies where pediatric and adult patients were combined together did show potential reductions in hypoglycemia (16,65,66).

### Real-time CGM Use in Type 2 Diabetes

Studies in people with type 2 diabetes are heterogeneous in design: in two, participants were using basal insulin with oral agents or oral agents alone (67,68); in one, individuals were on MDI alone (69). The findings in studies with MDI alone (69) and in two studies in people using oral agents with or without insulin (67,68) showed significant reductions in A1C levels. The Multiple Daily Injections and Continuous Glucose Monitoring in Diabetes (DIAMOND) study in people with type 2 diabetes on MDI showed a reduction in A1C but no reduction in hypoglycemia (69). Studies in individuals with type 2 diabetes on oral agents with or without insulin did not show reductions in rates of hypoglycemia (67,68).

### Intermittently Scanned CGM Device Use in Adults and Children With Diabetes

The original isCGM device (to which the majority of the published data applies) did not provide alarms and alerts but is an option used by many patients. There are relatively few RCT data proving benefit in people with diabetes, but there are multiple longitudinal and observational studies. One RCT, designed to show a reduction in episodes of hypoglycemia in patients with type 1 diabetes at higher risk for hypoglycemia, showed a significant benefit in terms of time spent in a hypoglycemic range ( $P < 0.0001$ ) (46). Another RCT, assessing the ability of

isCGM to prevent episodes of recurrent, severe hypoglycemia, showed no benefit (70). In one RCT of isCGM in people with type 2 diabetes on a variety of insulin regimens and with an initial A1C of  $\sim 8.8\%$ , no reduction in A1C was seen; however, the time spent in a hypoglycemic range was reduced by 43% (71). In a study of isCGM in individuals with type 2 diabetes on MDI, the A1C was reduced by 0.82% in the intervention group and 0.33% in the control group ( $P = 0.005$ ) with no change in rates of hypoglycemia (72). Multiple observational studies have shown benefit in terms of A1C reduction, reductions in hypoglycemia, and/or improvements in quality of life in both children and adults (31,41,73–78). An observational study from Belgium showed no improvements in A1C or quality of life after a year of isCGM use, with a reduction in episodes of severe hypoglycemia and time absent from work compared with patient recall of events during the 6 months prior to starting CGM (79).

There are several published reviews of data available on isCGM (80–83). The Norwegian Institute of Public Health conducted an assessment of isCGM clinical effectiveness, cost-effectiveness, and safety for individuals with type 1 and type 2 diabetes, based on data available to January 2017 (80). The authors concluded that, although there were few quality data available at the time of the report, isCGM may increase treatment satisfaction, increase time in range, and reduce frequency of nocturnal hypoglycemia, without differences in A1C or quality of life or serious adverse events. The Canadian Agency for Drugs and Technologies in Health reviewed existing data on isCGM performance and accuracy, hypoglycemia, effect on A1C, and patient satisfaction and quality of life and concluded that the system could replace SMBG, particularly in patients who require frequent monitoring (81). A 2020 systematic review of RCTs assessing efficacy and patient satisfaction with isCGM revealed improvements in A1C levels in some subgroups of patients (e.g., those with type 2 diabetes) but concluded that additional benefit in terms of time in range, glycemic variability, and hypoglycemia was unclear (30). Benefit was enhanced in individuals with type 1 diabetes when combined with a structured education

program. Another review showed some benefits in terms of A1C reduction as well as improvement in quality of life (84). A review that included studies conducted using a variety of trial designs, including prospective and retrospective cohort studies, showed overall a reduction in A1C ( $-0.26\%$ ) in people with type 1 and type 2 diabetes, but there was no difference in time in range or hypoglycemic episodes (83).

Other benefits are discussed in a review (82) that supported the use of isCGM as a more affordable alternative to rtCGM systems for individuals with diabetes who are on intensive insulin therapy. In many cases, isCGM is the preferred alternative compared with SMBG (85,86). It can also improve adherence to monitoring in patients who are in extremely poor control (87).

#### Real-time CGM Device Use in Pregnancy

One well-designed RCT showed a reduction in A1C levels in adult women with type 1 diabetes on MDI or CSII who were pregnant using CGM in addition to standard care, including optimization of pre- and postprandial glucose targets (88). It demonstrated the value of CGM in pregnancy complicated by type 1 diabetes by showing a mild improvement in A1C without an increase in hypoglycemia as well as reductions in large-for-gestational-age births, length of stay, and neonatal hypoglycemia (88). An observational cohort study that evaluated the glycemic variables reported using CGM found that lower mean glucose, lower standard deviation, and a higher percentage of time in target range were associated with lower risk of large-for-gestational-age births and other adverse neonatal outcomes (89). Use of the CGM-reported mean glucose is superior to use of estimated A1C, glucose management indicator, and other calculations to estimate A1C given the changes to A1C that occur in pregnancy (90). Two studies employing intermittent use of rtCGM showed no difference in neonatal outcomes in women with type 1 diabetes (91) or gestational diabetes mellitus (92).

#### Use of Professional and Intermittent CGM

Professional CGM devices, which provide retrospective data, either blinded or unblinded, for analysis, can be used to

identify patterns of hypo- and hyperglycemia (93). Professional CGM can be helpful to evaluate patients when either rtCGM or isCGM is not available to the patient or the patient prefers a blinded analysis or a shorter experience with unblinded data. It can be particularly useful to evaluate periods of hypoglycemia in patients on agents that can cause hypoglycemia in order to make medication dose adjustments. It can also be useful to evaluate patients for periods of hyperglycemia.

There are some data showing benefit of intermittent use of CGM (rtCGM or isCGM) in individuals with type 2 diabetes on noninsulin and/or basal insulin therapies (68,94). In these RCTs, patients with type 2 diabetes not on intensive insulin regimens used CGM intermittently compared with patients randomized to SMBG. Both early (68) and late improvements in A1C were found (68,94).

Use of professional or intermittent CGM should always be coupled with analysis and interpretation for the patient, along with education as needed to adjust medication and change lifestyle behaviors.

#### Side Effects of CGM Devices

Contact dermatitis (both irritant and allergic) has been reported with all devices that attach to the skin (95–97). In some cases this has been linked to the presence of isobornyl acrylate, which is a skin sensitizer and can cause an additional spreading allergic reaction (98–100). Patch testing can be done to identify the cause of the contact dermatitis in some cases (101). Identifying and eliminating tape allergens is important to ensure comfortable use of devices and enhance patient adherence (102–105). In some instances, use of an implanted sensor can help avoid skin reactions in those who are sensitive to tape (106,107).

## INSULIN DELIVERY

### Insulin Syringes and Pens

#### Recommendations

**7.16** For people with diabetes who require insulin, insulin syringes or insulin pens may be used for insulin delivery with consideration of patient preference, insulin type and dosing regimen,

cost, and self-management capabilities. **B**

**7.17** Insulin pens or insulin injection aids may be considered for patients with dexterity issues or vision impairment to facilitate the administration of accurate insulin doses. **C**

**7.18** Smart pens may be useful for some patients to help with dose capture and dosing recommendations. **E**

**7.19** U.S. Food and Drug Administration–approved insulin dose calculators/decision support systems may be helpful for titrating insulin doses. **E**

Injecting insulin with a syringe or pen is the insulin delivery method used by most people with diabetes (108,109), although inhaled insulin is also available. Others use insulin pumps or automated insulin delivery devices (see sections on those topics below). For patients with diabetes who use insulin, insulin syringes and pens are both able to deliver insulin safely and effectively for the achievement of glycemic targets. When choosing among delivery systems, patient preferences, cost, insulin type and dosing regimen, and self-management capabilities should be considered. It is important to note that while many insulin types are available for purchase as either pens or vials, others may only be available in one form or the other and there may be significant cost differences between pens and vials (see **Table 9.3** for a list of insulin product costs with dosage forms). Insulin pens may allow people with vision impairment or dexterity issues to dose insulin accurately (110–112), while insulin injection aids are also available to help with these issues. (For a helpful list of injection aids, see <http://main.diabetes.org/dforg/pdfs/2018/2018-cg-injection-aids.pdf>.) Inhaled insulin can be useful in people who have an aversion to injections.

The most common syringe sizes are 1 mL, 0.5 mL, and 0.3 mL, allowing doses of up to 100 units, 50 units, and 30 units of U-100 insulin, respectively. In a few parts of the world, insulin syringes still have U-80 and U-40 markings for older insulin concentrations and veterinary insulin, and U-500 syringes are available for the use of U-500 insulin. Syringes are generally used once but may be reused by the same individual in resource-limited

settings with appropriate storage and cleansing (113).

Insulin pens offer added convenience by combining the vial and syringe into a single device. Insulin pens, allowing push-button injections, come as disposable pens with prefilled cartridges or reusable insulin pens with replaceable insulin cartridges. Pens vary with respect to dosing increment and minimal dose, which can range from half-unit doses to 2-unit dose increments. U-500 pens come in 5-unit dose increments. Some reusable pens include a memory function, which can recall dose amounts and timing. “Smart” pens that can be programmed to calculate insulin doses and provide downloadable data reports are also available. These pens are useful to assist patient insulin dosing in real time as well as for allowing clinicians to retrospectively review the insulin doses that were given and make insulin dose adjustments (114).

Needle thickness (gauge) and length is another consideration. Needle gauges range from 22 to 33, with higher gauge indicating a thinner needle. A thicker needle can give a dose of insulin more quickly, while a thinner needle may cause less pain. Needle length ranges from 4 to 12.7 mm, with some evidence suggesting shorter needles may lower the risk of intramuscular injection. When reused, needles may be duller and thus injection more painful. Proper insulin injection technique is a requisite for obtaining the full benefits of insulin therapy. Concerns with technique and use of the proper technique are outlined in Section 9 “Pharmacologic Approaches to Glycemic Treatment” (<https://doi.org/10.2337/dc21-S009>).

Bolus calculators have been developed to aid in dosing decisions (115–119). These are subject to FDA approval to ensure safety in terms of dosing recommendations. People who are interested in using these systems should be encouraged to use those that are FDA approved. Provider input and education can be helpful for setting the initial dosing calculations with ongoing follow-up for adjustments as needed.

### Insulin Pumps

#### Recommendations

**7.20** Insulin pump therapy may be considered as an option for all adults and youth with type 1 diabetes who are able to safely manage the device. **A**

**7.21** Insulin pump therapy may be considered as an option for adults and youth with type 2 diabetes and other forms of diabetes who are on multiple daily injections who are able to safely manage the device. **B**

**7.22** Individuals with diabetes who have been successfully using continuous subcutaneous insulin infusion should have continued access across third-party payers. **E**

CSII, or insulin pumps, have been available in the U.S. for over 40 years. These devices deliver rapid-acting insulin throughout the day to help manage blood glucose levels. Most insulin pumps use tubing to deliver insulin through a cannula, while a few attach directly to the skin, without tubing.

Most studies comparing MDI with CSII have been relatively small and of short duration. However, a recent systematic review and meta-analysis concluded that pump therapy has modest advantages for lowering A1C ( $-0.30\%$  [95% CI  $-0.58$  to  $-0.02$ ]) and for reducing severe hypoglycemia rates in children and adults (120). There is no consensus to guide choosing which form of insulin administration is best for a given patient, and research to guide this decision-making is needed (121). Thus, the choice of MDI or an insulin pump is often based upon the individual characteristics of the patient and which is most likely to benefit them. Newer systems, such as sensor-augmented pumps and automatic insulin delivery systems, are discussed elsewhere in this section.

Adoption of pump therapy in the U.S. shows geographical variations, which may be related to provider preference or center characteristics (122,123) and socioeconomic status, as pump therapy is more common in individuals of higher socioeconomic status as reflected by race/ethnicity, private health insurance, family income, and education (123,124). Given the additional barriers to optimal diabetes care observed in disadvantaged groups (125), addressing the differences in access to insulin pumps and other diabetes technology may contribute to fewer health disparities.

Pump therapy can be successfully started at the time of diagnosis (126,127). Practical aspects of pump therapy initiation include assessment of patient and family

readiness (although there is no consensus on which factors to consider in adults [128] or pediatric patients), selection of pump type and initial pump settings, patient/family education of potential pump complications (e.g., diabetic ketoacidosis [DKA] with infusion set failure), transition from MDI, and introduction of advanced pump settings (e.g., temporary basal rates, extended/square/dual wave bolus).

Older individuals with type 1 diabetes benefit from ongoing insulin pump therapy. There are no data to suggest that measurement of C-peptide levels or antibodies predicts success with insulin pump therapy (129,130). Additionally, frequency of follow-up does not influence outcomes. Access to insulin pump therapy should be allowed/continued in older adults as it is in younger people.

Complications of the pump can be caused by issues with infusion sets (dislodgement, occlusion), which place patients at risk for ketosis and DKA and thus must be recognized and managed early (131); lipohypertrophy or, less frequently, lipodystrophy (132,133); and pump site infection (134). Discontinuation of pump therapy is relatively uncommon today; the frequency has decreased over the past few decades, and its causes have changed (134,135). Current reasons for attrition are problems with cost, wearability, dislike for the pump, suboptimal glycemic control, or mood disorders (e.g., anxiety or depression) (136).

### Insulin Pumps in Youth

The safety of insulin pumps in youth has been established for over 15 years (137). Studying the effectiveness of CSII in lowering A1C has been challenging because of the potential selection bias of observational studies. Participants on CSII may have a higher socioeconomic status that may facilitate better glycemic control (138) versus MDI. In addition, the fast pace of development of new insulins and technologies quickly renders comparisons obsolete. However, RCTs comparing CSII and MDI with insulin analogs demonstrate a modest improvement in A1C in participants on CSII (139,140). Observational studies, registry data, and meta-analysis have also suggested an improvement of glycemic control in participants on CSII (141–143). Although hypoglycemia was a major adverse effect of intensified insulin regimen in the

Diabetes Control and Complications Trial (DCCT) (144), data suggest that CSII may reduce the rates of severe hypoglycemia compared with MDI (143,145–147).

There is also evidence that CSII may reduce DKA risk (143,148) and diabetes complications, in particular, retinopathy and peripheral neuropathy in youth, compared with MDI (65). Finally, treatment satisfaction and quality-of-life measures improved on CSII compared with MDI (149,150). Therefore, CSII can be used safely and effectively in youth with type 1 diabetes to assist with achieving targeted glycemic control while reducing the risk of hypoglycemia and DKA, improving quality of life, and preventing long-term complications. Based on patient–provider shared decision-making, insulin pumps may be considered in all pediatric patients with type 1 diabetes. In particular, pump therapy may be the preferred mode of insulin delivery for children under 7 years of age (66). Because of a paucity of data in adolescents and youth with type 2 diabetes, there is insufficient evidence to make recommendations.

Common barriers to pump therapy adoption in children and adolescents are concerns regarding the physical interference of the device, discomfort with the idea of having a device on the body, therapeutic effectiveness, and financial burden (141,151).

### Insulin Pumps in Patients With Type 2 and Other Types of Diabetes

Traditional insulin pumps can be considered for the treatment of people with type 2 diabetes who are on MDI as well as those who have other types of diabetes resulting in insulin deficiency, for instance, those who have had a pancreatectomy and/or individuals with cystic fibrosis (152–156). Similar to data on insulin pump use in people with type 1 diabetes, reductions in A1C levels are not consistently seen in individuals with type 2 diabetes when compared with MDI, although they have been in some studies (154,157). Use of insulin pumps in insulin-requiring patients with any type of diabetes may improve patient satisfaction and simplify therapy (130,152).

For patients judged to be clinically insulin deficient who are treated with an intensive insulin regimen, the presence or absence of measurable C-peptide levels does not correlate with response to

therapy (130). Another pump option in people with type 2 diabetes is a disposable patchlike device, which provides a continuous, subcutaneous infusion of rapid-acting insulin (basal) as well as 2-unit increments of bolus insulin at the press of a button (153,155,158). Use of an insulin pump as a means for insulin delivery is an individual choice for people with diabetes and should be considered an option in patients who are capable of safely using the device.

## Combined Insulin Pump and Sensor Systems

### Recommendations

- 7.23** Sensor-augmented pump therapy with automatic low glucose suspend may be considered for adults and youth with diabetes to prevent/mitigate episodes of hypoglycemia. **B**
- 7.24** Automated insulin delivery systems may be considered in youth and adults with type 1 diabetes to improve glycemic control. **A**
- 7.25** Individual patients may be using systems not approved by the U.S. Food and Drug Administration, such as do-it-yourself closed-loop systems and others; providers cannot prescribe these systems but should provide safety information/troubleshooting/backup advice for the individual devices to enhance patient safety. **E**

### Sensor-Augmented Pumps

Sensor-augmented pumps that suspend insulin when glucose is low or predicted to go low within the next 30 min have been approved by the FDA. The Automation to Simulate Pancreatic Insulin Response (ASPIRE) trial of 247 patients with type 1 diabetes and documented nocturnal hypoglycemia showed that sensor-augmented insulin pump therapy with a low glucose suspend function significantly reduced nocturnal hypoglycemia over 3 months without increasing A1C levels (51). In a different sensor-augmented pump, predictive low glucose suspend reduced time spent with glucose <70 mg/dL from 3.6% at baseline to 2.6% (3.2% with sensor-augmented pump therapy without predictive low glucose suspend) without rebound hyperglycemia during a 6-week randomized crossover trial (159). These devices may offer



the opportunity to reduce hypoglycemia for those with a history of nocturnal hypoglycemia. Additional studies have been performed, in adults and children, showing the benefits of this technology (160–162).

#### **Automated Insulin Delivery Systems**

Automated insulin delivery systems increase and decrease insulin delivery based on sensor-derived glucose level to begin to approximate physiologic insulin delivery. These systems consist of three components: an insulin pump, a continuous glucose sensor, and an algorithm that determines insulin delivery. With these systems, insulin delivery can not only be suspended but also increased or decreased based on sensor glucose values. While eventually insulin delivery in closed-loop systems may be truly automated, currently meals must be announced. A so-called hybrid approach, hybrid closed-loop, has been adopted in first-generation closed-loop systems and requires users to bolus for meals and snacks. Multiple studies, using a variety of systems with varying algorithms, pump, and sensors, have been performed in adults and children (163–173). Evidence suggests such systems may reduce A1C levels and improve time in range (174–178). They may lower the risk of exercise-related hypoglycemia (179) and may have psychosocial benefits (180–183). Use of these systems depends on patient preference and selection of patients (and/or caregivers) who are capable of safely and effectively using the devices.

Some people with type 1 diabetes have been using “do-it-yourself” (DIY) systems that combine a pump and an rtCGM with a controller and an algorithm designed to automate insulin delivery (184–187). These systems are not approved by the FDA, although there are efforts underway to obtain regulatory approval for them. The information on how to set up and manage these systems is freely available on the internet, and there are internet groups where people inform each other as to how to set up and use them. Although these systems cannot be prescribed by providers, it is important to keep patients safe if they are using these methods for automated insulin delivery. Part of this entails making sure people have a “backup plan” in case of pump failure. Additionally, in most DIY systems, insulin doses are adjusted based on the pump settings for basal rates,

carbohydrate ratios, correction doses, and insulin activity. Therefore, these settings can be evaluated and changed based on the patient’s insulin requirements.

#### **Digital Health Technology**

##### **Recommendation**

**7.26** Systems that combine technology and online coaching can be beneficial in treating prediabetes and diabetes for some individuals. **B**

Increasingly, people are turning to the internet for advice, coaching, connection, and health care. Diabetes, in part because it is both common and numeric, lends itself to the development of apps and online programs. The FDA approves and monitors clinically validated, digital, usually online, health technologies intended to treat a medical or psychological condition; these are known as digital therapeutics or “digiceuticals” (188). Other applications, such as those that assist in displaying or storing data, encourage a healthy lifestyle or provide limited clinical data support. Therefore, it is possible to find apps that have been fully reviewed and approved and others designed and promoted by people with relatively little skill or knowledge in the clinical treatment of diabetes.

An area of particular importance is that of online privacy and security. There are established cloud-based data collection programs, such as Tidepool, Glooko, and others, that have been developed with appropriate data security features and are compliant with the U.S. Health Insurance Portability and Accountability Act of 1996. These programs can be useful for monitoring patients, both by the patients themselves as well as their health care team (189). Consumers should read the policy regarding data privacy and sharing before entering data into an application and learn how they can control the way their data will be used (some programs offer the ability to share more or less information, such as being part of a registry or data repository or not).

There are many online programs that offer lifestyle counseling to aid with weight loss and increase physical activity (190). Many of these include a health coach and can create small groups of similar patients in social networks. There are programs that aim to treat prediabetes and prevent progression to diabetes, often following the model of the Diabetes Prevention Program

(191,192). Others assist in improving diabetes outcomes by remotely monitoring patient clinical data (for instance, wireless monitoring of glucose levels, weight, or blood pressure) and providing feedback and coaching (193–198). There are text messaging approaches that tie into a variety of different types of lifestyle and treatment programs, which vary in terms of their effectiveness (199,200). For many of these interventions, there are limited RCT data and long-term follow-up is lacking. But for an individual patient, opting into one of these programs can be helpful and, for many, is an attractive option.

#### **Inpatient Care**

##### **Recommendation**

**7.27** Patients using diabetes devices should be allowed to use them in an inpatient setting when proper supervision is available. **E**

Patients who are comfortable using their diabetes devices, such as insulin pumps and sensors, should be given the chance to use them in an inpatient setting if they are competent to do so (201,202). Patients who are familiar with treating their own glucose levels can often adjust insulin doses more knowledgeably than inpatient staff who do not personally know the patient or their management style. However, this should occur based on the hospital’s policies for diabetes management, and there should be supervision to be sure that the individual can adjust their insulin doses in a hospitalized setting where factors such as infection, certain medications, immobility, changes in diet, and other factors can impact insulin sensitivity and the response to insulin.

With the advent of the coronavirus disease 2019 pandemic, the FDA has allowed CGM use in the hospital for patient monitoring (203). This approach has been employed to reduce the use of personal protective equipment and more closely monitor patients, so that medical personnel do not have to go into a patient room solely for the purpose of measuring a glucose level. Studies are underway to assess the effectiveness of this approach, which may ultimately lead to the routine use of CGM for monitoring hospitalized patients (204,205).

#### **The Future**

The pace of development in diabetes technology is extremely rapid. New

approaches and tools are available each year. It is hard for research to keep up with these advances because by the time a study is completed, newer versions of the devices are already on the market. The most important component in all of these systems is the patient. Technology selection must be appropriate for the individual. Simply having a device or application does not change outcomes unless the human being engages with it to create positive health benefits. This underscores the need for the health care team to assist the patient in device/program selection and to support its use through ongoing education and training. Expectations must be tempered by reality—we do not yet have technology that completely eliminates the self-care tasks necessary for treating diabetes, but the tools described in this section can make it easier to manage.

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