**MANAGEMENT OF TYPE 2 DIABETES: SELECTING AMONGST AVAILABLE PHARMACOLOGICAL AGENTS**

**Emily B Schroeder, MD, PhD,** Parkview Health, Fort Wayne, IN, [Emily.Schroeder@parkview.com](mailto:Emily.Schroeder@parkview.com)

**Updated July 27, 2022**

**ABSTRACT**

In the early 1990’s, clinicians’ choices for pharmacological management of type 2 diabetes were limited to insulin, sulfonylureas, and metformin. Since then, multiple classes of agents have been discovered, approved, and put into clinical use. Through a series of cardiovascular outcome trials and other clinical trials, some classes of agents have been found to have benefits on atherosclerotic cardiovascular disease, congestive heart failure, and chronic kidney disease, sometimes independent of glycemic control. As a result, diabetes management has shifted away from a “one size fits all” care to an individualized approach for each patient. Important factors to consider include efficacy, cost, side effects, adherence and treatment burden, comorbidities, mechanisms of action, and non-glycemic effects on atherosclerotic cardiovascular disease, congestive heart failure, and chronic kidney disease. The goal of this chapter is to discuss an approach to pharmacological management that reviews current guidelines, discusses choosing appropriate glycemic targets, and presents the rationale for choosing certain medications in different situations.

# INTRODUCTION

Foundational to the treatment of type 2 diabetes is glucose control. Diabetes increases the risk of microvascular and macrovascular complications, as well as mortality, morbidity, and healthcare costs. While lifestyle interventions are the basis for glucose control, most people will eventually need one or more pharmacologic treatments. This is because type 2 diabetes is a disease characterized by progressive beta-cell loss and dysfunction, leading to deterioration of metabolic control over time. Because of the growth in the number of antihyperglycemic agents in recent years, there are now more choices than ever in terms of how to achieve glucose control. Agents should be chosen with a goal of achieving glucose control, reducing risk of microvascular and macrovascular disease, and minimizing treatment burden (1-8)

# SELECTION OF GLYCEMIC TARGETS

The first step in the approach to glycemic control in type 2 diabetes is the selection of an appropriate glycemic target. Glycemic control can be measured in a variety of ways, including hemoglobin A1c, self-monitoring of blood glucose (SMBG), and continuous glucose monitoring. Continuous glucose monitoring (CGM) makes available a range of metrics, including time in target, percent of time with hypoglycemia, percent of time with hyperglycemia, and glucose variability (as determined by standard deviation or coefficient of variation). Hemoglobin A1c has traditionally been the metric used in clinical trials. However, there is increasing interest in the use of time in range from CGM, as it is not subject to the same measurement limitations as hemoglobin A1c, responds more quickly to changes in glucose, and better reflects glucose variability (4, 6, 9, 10). Note that the hemoglobin A1c may not be accurate in conditions in which there is altered red blood cell turnover or in the presence of some hemoglobin variants. Further details can be found in the Endotext chapter (Monitoring Techniques-Continuous Glucose Monitoring, Mobile Technology, Biomarkers of Glycemic Control (11)).

Professional societies such as the American Diabetes Association (ADA) and the American Association of Clinical Endocrinology (AACE) differ somewhat on their recommendations for glycemic targets. However, the tenant of individualization of glycemic targets is central to both of their recommended approaches. The ADA recommendations are shown in Table 1, and were modified to include time in range targets from CGMs in 2021 (4, 12). In contrast, the AACE clinical guidelines state that “An A1c of < 6.5% (48 mmol/mol) is considered optimal if it can be achieved in a safe and affordable manner, but higher targets may be appropriate for certain individuals and may change for a given individual over time.” (1)

|  |
| --- |
| **Table 1. Glycemic Target Recommendations from the American Diabetes Association 2021 Standards of Medical Care in Diabetes** |
| An A1c goal for many nonpregnant adults of <7% without significant hypoglycemia is appropriate. |
| If using ambulatory glucose profile/glucose management indicator to assess glycemia, a parallel goal for many non-pregnant adults is time in range of >70% with time below range <4% and time <54 mg/dL <1%. |
| On the basis of provider judgement and patient preference, achievement of lower A1c levels than the goal of 7% may be acceptable and even beneficial if it can be achieved safely without significant hypoglycemia or other adverse effects of treatment. |
| Less stringent A1c goals (such as <8% [64 mmol/mol]) may be appropriate for patients with limited life expectancy or where the harms of treatment are greater than the benefits. |

Adapted from American Diabetes Association (4).

The differing recommendations of the ADA and AACE are based, in part, on considerations and interpretations of the ADVANCE (Action in Diabetes and Vascular Disease: Preterax and Diamicron MR Controlled Evaluation), ACCORD (Action to Control Cardiovascular Risk in Diabetes), and VADT (Veterans Affairs Diabetes Trial) trials. A discussion of these trials is outside the scope of this chapter, but excellent summaries can be found elsewhere (1, 4, 13-17).

The primary risk of lower glycemic targets is hypoglycemia. In general, rates of hypoglycemia are unappreciated (18). A meta-analysis has found that among individuals with type 2 diabetes on insulin, the average incidence of hypoglycemia is 23 mild or moderate events and 1 severe episode annually (19). In 2015, there were 235,000 emergency room visits in the U.S. for hypoglycemia among adults with type 2 diabetes. This corresponds to a rate of 10.2 per 1,000 adults with diabetes (20). Hypoglycemia is associated with significant morbidity, mortality, and decreased quality of life. For example, among Medicare beneficiaries in 2010, hospitalizations for hypoglycemia were associated with an adjusted 30-day readmission rate of 18.1% and 30-day mortality rate of 5% (21). The use of glucose lowering drugs with a low potential for hypoglycemia allows one to safely achieve lower glycemic targets.

Other risks of lower glycemic targets include increased burden of treatment, polypharmacy, cost, and side effects from particular medications (weight gain, pancreatitis, etc.). Lower glucose targets early in the course of the disease can have a favorable legacy effect which can last for years later. Conversely, individuals with multiple comorbidities and complications from diabetes show less benefit from lower glucose targets. Factors to consider in the individualization of glycemic targets are shown in Table 2 (4).

|  |  |
| --- | --- |
| Table 2. Factors Guiding Individualization of Glycemic Targets | |
| **Favoring lower glucose targets** | **Favoring higher glucose targets** |
| Low risks associated with hypoglycemia and other drug adverse effects | High risks associated with hypoglycemia and other drug adverse effects |
| Newly diagnosed | Long standing diabetes |
| Long life expectancy | Short life expectancy |
| No important comorbidities | Many comorbidities |
| No vascular complications | Severe vascular complications |
| Highly motivated patient with excellent self-care capabilities | Patient preference for less burdensome therapy |
| Available resources and support system | Limited resources and support system |

Adapted from American Diabetes Association (4).

For most patients, an A1c goal of <7% will be appropriate. However, for older patients with multiple comorbidities, an A1c goal of 8-8.5% is more appropriate, and will minimize risks of hypoglycemia, increased treatment burden, and potential side effects. Major exceptions to this goal would be patients with a short life expectancy for any reason (severe comorbidities, very old age, etc.) in which the risks of tight control outweigh the long-term benefits in reduction of complications that may never be realized. In these populations, the goal is to avoid hypoglycemia and symptomatic hyperglycemia (4, 6).

# GENERAL PRINCIPLES

Table 3 outlines basic principles of type 2 diabetes management, as formulated by the AACE and the American College of Endocrinology.

|  |
| --- |
| **Table 3. Principles of Type 2 Diabetes Management** |
| Lifestyle modification underlies all therapy (e.g.**,** weight control, physical activity, sleep, etc.) |
| Avoid hypoglycemia |
| Avoid weight gain |
| Individualize all glycemic targets |
| Optimal A1c is <6.5% or as close to normal as is safe and achievable |
| Therapy choices are patient centric based on A1c at presentation and shared decision-making |
| Choice of therapy reflects presence of atherosclerotic cardiovascular disease, congestive heart failure, and renal status |
| Comorbidities must be managed for comprehensive care |
| Get to goal as soon as possible – adjust at < 3 months until at goal |
| Choice of therapy includes ease of use and affordability |
| Continuous glucose monitoring is highly recommended, as available, to assist patients in reaching goals safely |

Adapted from the American Association of Clinical Endocrinology and the American College of Endocrinology (1).

Specific medication choices should be tailored to the needs of the individual patient. Important factors to consider include initial A1c, duration of diabetes, comorbidities, cardiac, cerebrovascular and renal status, cost, risk of hypoglycemia, available social supports, and patient preference.

**Classes of Antihyperglycemic Medications**

The number of classes of diabetes medications available have increased greatly since the 1990’s, as shown in Figure 1. In 2022 a new type of incretin was added to the antihyperglycemic armamentarium – a combined GIP/GLP-1 receptor agonist (22-26). A thorough discussion of the available medication types can be found in other Endotext chapters, including Oral and Injectable (Non-Insulin) Pharmacologic Agents for Treatment of Type 2 Diabetes and Insulin – Pharmacotherapy, Therapeutic Regimens and Principles of Intensive Insulin Therapy (27, 28).

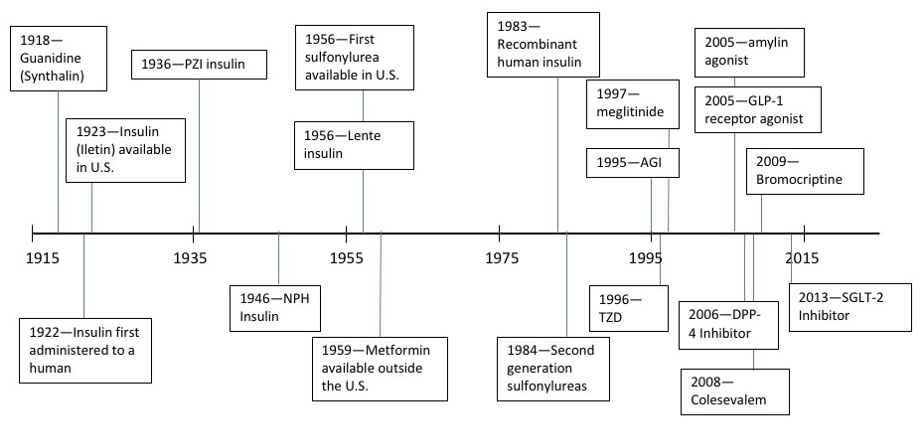


Figure 1. The History of Antihyperglycemic Agents. Figure adapted from White (29).

It is recognized that diabetes effects many organ systems throughout the body. Because of the multiple abnormal pathways, different medications can target different defects, and therefore work in a complementary fashion (see Table 4). Understanding has grown from the original “terrible triumvirate” with abnormalities of the beta cell (reduced insulin secretion), the liver (increased endogenous glucose production) and the peripheral insulin resistance. Overtime there was recognition of the “ominous octet”, and now there is understanding of even more pathways/defects (30-32). Characteristics of the most commonly used medications are shown in Tables 5 and 6.

|  |  |  |
| --- | --- | --- |
| **Table 4. Pathways in the Treatment of Type 2 Diabetes** | | |
| **Pathway** | **Defect** | **Medication classes** |
| Beta cell dysfunction | Decreased beta cell function and mass | Incretins, sulfonylureas, meglitinides |
| Incretin effect | Decrease in the incretin effect | Incretins |
| Alpha cells | Increase in glucagon | Incretins, pramlintide |
| Adipose tissue | Insulin resistance, increased lipolysis | Metformin, thiazolidinediones |
| Muscle | Insulin resistance, decreased peripheral glucose uptake | Metformin, thiazolidinediones |
| Liver | Insulin resistance, increased glucose production | Metformin, thiazolidinediones |
| Brain | Increased appetite, decreased morning dopamine surge, increased sympathetic tone | Incretins, dopamine agonists, appetite suppressants |
| Colon/biome | Abnormal microbiome, possible decreased GLP-1 secretion | Probiotics, incretins, metformin |
| Immune dysregulation/inflammation |  | Incretins, anti-inflammatories, immune modulators |
| Stomach/small intestine | Increased rise of glucose absorption | Incretins, pramlintide, alpha glucosidase inhibitors |
| Kidney | Increased glucose reabsorption | SGLT-  2 inhibitors |

GLP-1 = glucagon-like peptide 1; SGLT-2 = sodium-glucose co-transporter 2. Adapted from Schwartz (32).

|  |  |
| --- | --- |
| Table 5. Antihyperglycemic Agents and Mechanisms of Action | |
| **Class** | **Primary Mechanism of Action** |
| α-Glucosidase inhibitors | * Delay carbohydrate absorption from intestine |
| Amylin analogue | * Decrease glucagon secretion * Slow gastric emptying * Increase satiety |
| Biguanide | * Decrease hepatic glucose production * Increase glucose uptake in muscle |
| Bile acid sequestrant | * Decrease hepatic glucose production? * Increase incretin levels? |
| DPP-4 inhibitors | * Increase glucose-dependent insulin secretion * Decrease glucagon secretion |
| Dopamine-2 agonist | * Activates dopaminergic receptors |
| Meglitinides | * Increase insulin secretion |
| GLP-1 receptor agonists / combined GIP and GLP-1 receptor agonists | * Increase glucose-dependent insulin secretion * Decrease glucose secretion * Slow gastric emptying * Increase satiety |
| SGLT-2 inhibitors | * Increase urinary excretion of glucose |
| Sulfonylureas | * Increase insulin secretion |
| Thiazolidinediones | * Increase glucose uptake in muscle and fat * Decrease hepatic glucose production |

DDP-4 = dipeptidyl peptidase 4; GLP-1 = glucagon-like peptide 1; SGLT-2 = sodium-glucose co-transporter 2. Adapted from AACE 2015 and slideshow (2, 33)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 6. Characteristics of Commonly Used Antihyperglycemic Medication Classes** | | | | | | |
| **Drugs** | **Ability to Lower Glucose** | **Risk of Hypoglycemia** | **Weight Change** | **Effect on ASCVD** | **Effect on CHF** | **Effect on Renal Disease** |
| 2nd generation SU | High | Yes | Increase | Neutral | Neutral | Neutral |
| Metformin | High | No | Neutral-modest weight loss | Potential benefit | Neutral | Neutral |
| TZDs | High | No | Increase | Potential benefit (pioglitazone) | Increased | Neutral |
| DPP-4 inhibitors | Intermediate | No | Neutral | Neutral | Potential increase (saxagliptin, alogliptin) | Neutral |
| SGLT-2 inhibitors | Intermediate | No | Decrease | Potential benefit | Benefit | Benefit – reduced progression of renal failure |
| GLP-1 receptor agonists | High | No | Decrease | Benefit | Neutral-Potential Benefit | Benefit-decreased proteinuria |

DDP-4 = dipeptidyl peptidase 4; GLP-1 = glucagon-like peptide 1; SGLT-2 = sodium-glucose co-transporter 2; SU = sulfonylurea; TZD = thiazolidinediones. Adapted from American Diabetes Association and Endotext Chapter Pharmacological Agents for the Treatment of Type 2 Diabetes (5, 27)

**Therapeutic Inertia**

Reassessment of patient’s achievement of their glycemic goals as well as the appropriateness of these goals at regular intervals is necessary. In diabetes, therapeutic inertia can include both the failure to advance or to de-intensify treatment when appropriate to do so. Failure to escalate therapy when appropriate is associated with worse microvascular and macrovascular outcomes and higher health costs (34, 35). Furthermore, several studies have shown that achieving A1c targets early in the course of the disease is associated with maintaining lower A1c levels for longer (35-37). Delays in appropriate deintensification of therapy is also a widespread problem (35, 38, 39). A number of factors contribute to therapeutic inertia, many of which can be classified as patient-related factors, physician-related factors, and health care system factors (see Table 7) (40). In addition, societal level factors, such as health care payment models, society inequity, and social determinants of health care contribute to therapeutic inertia.

|  |  |  |
| --- | --- | --- |
| Table 7. Factors Contributing to Therapeutic Inertia in Diabetes Care | | |
| **Patient-related** | **Physician-related** | **Healthcare system-related** |
| Denial of disease | Time constraints | No clinical guidelines |
| Lack of awareness of progressive nature of disease leading to feeling of “failure” | Lack of support | No disease registry |
| Lack of awareness of implications of poor glycemic control | Concerns over costs of treatment and testing | No visit planning |
| Fear of side effects (hypoglycemia, weight gain) | Reactive rather than proactive care | No active outreach to patients |
| Concerns over ability to manage more complicated treatment regimens | Underestimation of patient’s needs | No decision support |
| Too many medications | Lack of information/understanding of new treatment options | No team approach to care |
| Treatment costs | Lack of information on side effects/fear of causing harm | Poor communication between physician and staff |
| Poor communication with physician | Lack of clear guidance on individualizing treatment |  |
| Lack of support | Concern over patient’s ability to manage for complicated treatment regimens |  |
| Lack of trust in physician | Concerns over patient adherence |  |

Adapted from Okemah (40).

# ALGORITHM FOR ANTIHYPERGLYCEMIC MEDICATIONS

There are a number of algorithms available to guide the choice of antihyperglycemic medications for type 2 diabetes. These include algorithms from the American Diabetes Association, the American Association of Clinical Endocrinology and American College of Endocrinology, and the European Society of Cardiology and the European Association for the Study of Diabetes, among others. While these differ in the details, they share a similar approach (1-3, 5, 28, 41, 42). The cornerstone of treatment of type 2 diabetes is comprehensive lifestyle education. This includes diabetes self-management education and support (DSMES), medical nutrition therapy, routine physical activity, smoking cessation counseling, and psychosocial care. DSMES has been shown to result in improved quality of life, reduced all-cause mortality risk, and health care costs (43-49). Specific lifestyle goals, if possible, include at least 150 minutes of moderate exercise per week and a reduction in body weight by 5-10% (1, 49). Weight loss in type 2 diabetes can improve glycemic control, result in diabetes remission, and cause improvements in blood pressure, lipids, hepatic steatosis, obstructive sleep apnea, osteoarthritis, and renal function (1, 2, 50-53).

**Initiating Treatment**

For individuals requiring pharmacologic treatment, monotherapy is a reasonable approach for patients whose A1c is close to goal. Historically, metformin has been recommended as the first line agent, unless there are contraindications. However, in light of the growing evidence supporting use of GLP-1 receptor agonists and/or SGLT-2 inhibitors to decrease atherosclerotic cardiovascular disease (ASCVD), heart failure, and/or chronic kidney disease, there has been movement to consider use of these agents before metformin (1, 5, 42). In 2022, the ADA modified its previous recommendations that metformin be used as a first line agent in the absence of contraindications (54). The ADA now recommends that “First-line therapy depends on comorbidities, patient-centered treatment factors, and management needs and generally includes metformin and comprehensive lifestyle modification…. Other medications (glucagon-like peptide 1 receptor agonists, sodium-glucose cotransporter 2 inhibitors), with or without metformin based on glycemic needs, are appropriate initial therapy for individuals with type 2 diabetes with or at high risk for atherosclerotic cardiovascular disease, heart failure, and/or chronic kidney disease” (5). AACE recommends that “The choice of diabetes therapies must be individualized based on attributes specific to both patients and the medications themselves…. The choice of therapy depends on the patients cardiac, cerebrovascular, and renal status” (1). Thus, the ADA and AACE are now in agreement that GLP-1 receptor agonists and SGLT-2 inhibitors should be considered as first line agents in certain patients (1, 5). Of note, use of these agents as first line treatment can often still be limited by cost and insurance coverage considerations.

**Combination Therapy**

Many patients will require combination treatment. Initial combination treatment should be considered in individuals with an elevated A1c. AACE recommends initial combination treatment for A1c > 7.5%, while the ADA recommends initial combination treatment for patients with A1c 1.5-2% above their glycemic target (1, 5). For individuals with A1c > 9-10% with symptoms of hyperglycemia or catabolism, insulin therapy should be the initial treatment. For individuals with A1c > 9-10% without symptoms, initial treatment with dual or triple therapy without insulin can be considered, although insulin is often needed. Generally, medications are added, instead of substituting medications. This is because of the progressive nature of diabetes, and because medications can be chosen that act in complementary manners. Important exceptions to this is that incretin agents should not be combined (i.e. DDP-4 inhibitors and GLP-1 receptor agonists), and that sulfonylureas and meglitinide are typically stopped when prandial insulin is initiated.

# Durability

The natural history of type 2 diabetes is one of progressive beta cell failure that leads to the need to intensify a medical regimen over time. This generally means starting with one medication and adding others as needed to meet glycemic goals. Some medications are able to maintain glycemic control for longer than others, and thus have a more favorable effect on the natural history of diabetes, likely by successfully modifying and improving the underlying abnormal physiology.

In general, sulfonylureas have been found to be less durable than other diabetes medications. For example, in the A Diabetes Outcome Progression Trial (ADOPT), among patients with newly diagnosed diabetes, the 5-year failure rate for sulfonylureas was 15% for rosiglitazone, 21% for metformin, and 34% for glyburide (55). While sulfonylureas are able to affect an increase in insulin production, they are unable to correct the underlying beta cell dysfunction.

**Metformin**

Metformin is traditionally considered the first line agent due to low risk of hypoglycemia, good antihyperglycemic efficacy, ability to promote weight loss, and cost. Compared to sulfonylureas, its effects tend to be more durable, and there is stronger data supporting its cardiovascular safety (56). Metformin commonly causes gastrointestinal side effects, which can often be minimized by starting at a low dose and gradually titrating and using extended release formulations (57). While the maximum dose is 850 mg three times a day, most people do not titrate past 1000 mg twice a day. Metformin is associated with an increased risk of lactic acidosis, and should not be used in individuals at increased risk of lactic acidosis, such as in chronic kidney disease or hepatic disease. While metformin used to have contraindications based on creatinine levels, in 2016 the FDA changed these recommendations (58). Current renal dosing guidance is shown in Table 8 (1, 5, 59-62). Metformin can also lead to vitamin B12 malabsorption and/or deficiency, which can lead to anemia and peripheral neuropathy, and so B12 levels should be monitored periodically (63).

|  |  |
| --- | --- |
| **Table 8. Metformin Dosing Recommendations** | |
| **eGFR (mL/min/1.73 m2)** | **Recommendation** |
| > 60 | No adjustments  Monitor annually |
| 45-60 | No adjustments  Monitor every 3-6 months |
| 30-45 | Initiation generally not recommended, but can be considered  Continuation of therapy: maximum dose of 500 mg twice a day |
| < 30 | Contraindicated |

eGFR = estimated glomerular filtration rate. Adapted from multiple sources (1, 5, 59-62).

**Patients with ASCVD, Congestive Heart Failure, or Chronic Kidney Disease**

For patients with high-risk or established ASCVD, heart failure, or chronic kidney disease, GLP-1 receptor agonists and SGLT-2 inhibitors should be considered independent of baseline A1c, individualized A1c target, or metformin use. As described in Endotext chapter Pharmacological Agents for the Treatment of Type 2 Diabetes, the GLP-1 receptor agonists dulaglutide, liraglutide, and semaglutide have been shown to reduce cardiovascular events in individuals at high-risk or with established ASCVD (1, 5, 27, 64-66). In secondary analysis, improvement in renal outcomes were also seen in prespecified secondary outcomes in these trials (LEADER, SUSTAIN-6, and REWIND) (64-66). Markers of high-risk of ASCVD can include patients 55 years or older with coronary, carotid, or lower-extremity artery stenosis of >50% or left ventricular hypertrophy (5). Contraindications to the use of GLP-1 receptor agonists include history of pancreatitis and a personal or family history of medullary thyroid carcinoma or multiple endocrine neoplasia 2A or 2B. Some agents (exenatide, lixisenatide) are not approved in the setting of chronic kidney disease. Increase in the progression of retinopathy was seen in the pivotal trial of semaglutide, but it is unclear whether that was an effect specific to the medication or a consequence of the rapid glucose lowering (65). Tirzepatide is a novel combined GIP and GLP-1 receptor agonist which has showed substantial A1c lowering and weight loss (22-26). The tirzepatide cardiovascular disease outcome trials are still ongoing.

SGLT-2 inhibitors have been shown to reduce diabetic kidney disease progression, hospitalizations for heart failure, and ASCVD (5, 7, 8, 67-82). See in Endotext chapter Pharmacological Agents for the Treatment of Type 2 Diabetes for additional details (27). SGLT-2 inhibitors with benefits on progression of diabetic kidney disease include canagliflozin, empagliflozin, and dapagliflozin. SGLT-2 inhibitors with proven effects on ASCVD include empagliflozin and canagliflozin. SGLT-2 inhibitors with proven effects on heart failure include empagliflozin, canagliflozin, dapagliflozin, and ertugliflozin. SGLT-2 inhibitors are contraindicated in patients with a history of or increased risk of diabetic ketoacidosis, due to increased risk of euglycemic diabetic ketoacidosis with these agents. In addition, they should be used caution in individuals with frequent bacterial urinary tract infections or genitourinary yeast infections, high risk for fractures and falls, foot ulceration, or other factors predisposing to diabetic ketoacidosis.

An area of ongoing discussion is the use of SGLT-2 inhibitors in individuals who already have advanced chronic kidney disease. At estimated glomerular filtration rate (eGFR) < 45 mL/min/1.73m2, SGLT-2 inhibitors are unlikely to result in substantial glucose lowering. However, they have been shown to have beneficial effects on delaying the progression of chronic kidney disease in patients with eGFRs down to 25 mL/min/1.73 m2 (7). Patients with advanced chronic kidney disease on SGLT-2 inhibitors must be monitored closely, and counselled to maintain adequate fluid intake and avoid hypoglycemia.

Thus, for individuals with established ASCVD or at high risk for ASCVD, either a GLP-1 receptor agonist with proven cardiovascular disease benefits (dulaglutide, liraglutide, semaglutide) or an SGLT-2 inhibitor with proven cardiovascular disease benefit (empagliflozin, canagliflozin) should be strongly considered, potentially as a first line agent. For patients with heart failure, a SGLT-2 inhibitor with a proven benefit for heart failure hospitalizations should be considered, potentially as a first line agent. For patients with chronic kidney disease and albuminuria, a SGLT-2 inhibitor should be strongly considered regardless of glycemic control. If SGLT-2 inhibitors are not tolerated or are contraindicated, a GLP-1 receptor agonist can be considered. For patients with chronic kidney disease without albuminuria, either a GLP-1 receptor agonist with proven cardiovascular disease benefit or a SGLT-2 inhibitor with proven cardiovascular disease benefit can be considered. In addition, combination therapy with GLP-1 receptor agonist and SGLT-2 inhibitor likely has synergistic effects on glucose lowering and CVD prevention, and thus should be considered (8, 83).

Note that some SGLT-2 inhibitors and GLP-1 receptor agonists have indications for individuals without diabetes (see Table 9).

|  |  |
| --- | --- |
| Table 9. Antihyperglycemic Medications with Indications in Individuals Without Diabetes | |
| **Medication** | **Indication** |
| Liraglutide (Saxenda) | As an adjunct to a reduced calorie diet and increased physical activity for chronic weight management in adults with an initial BMI of 30 kg/m2 or greater or BMI of 27 kg/m2 and at least one weight-related comorbid condition (e.g. hypertension, type 2 diabetes mellitus, dyslipidemia) (84) |
| Semaglutide (Wegovy) | As an adjunct to a reduced calorie diet and increased physical activity for chronic weight management in adults with an initial BMI of 30 kg/m2 or greater or BMI of 27 kg/m2 and at least one weight-related comorbid condition (e.g. hypertension, type 2 diabetes mellitus, dyslipidemia) (85) |
| Dapagliflozin (Farxiga) | Reduce the risk of cardiovascular death and hospitalization for heart failure in adults with heart failure with reduced ejection fraction (NYHA class II-IV) (86) |
| Dapagliflozin (Farxiga) | Reduce the risk of sustained eGFR decline, end stage kidney disease, cardiovascular death and hospitalization for heart failure in adults with chronic kidney disease at risk for progression (86) |
| Empagliflozin (Jardiance) | Reduce the risk of cardiovascular death plus hospitalization for heart failure in adults with heart failure and reduced ejection fraction (87) |

BMI = body mass index; eGFR = estimated glomerular filtration rate; NYHA = New York Heart Association.

**Patients at Risk for Hypoglycemia**

While hypoglycemia should be avoided for all patients, it is especially important in patients with hypoglycemia unawareness, in older patients, and in patients with multiple comorbidities or diabetes complications. Medications with a higher risk of hypoglycemia should be avoided in these patients, and include sulfonylureas, meglitinides, and insulin. Medications to consider with a low risk of hypoglycemia include metformin, DPP-4 inhibitors, GLP-1 receptor agonists, SGLT-2 inhibitors, or thiazolidinediones.

If a sulfonylurea must be added, a later generation agent should be chosen. Meglitinides also can be considered in some patients, and generally have a lower risk of hypoglycemia (and also less A1c lowering potential) than sulfonylureas. Basal insulins with lower risk of hypoglycemia can also be chosen. The risk of hypoglycemia is lowest for degludec and glargine U-300, followed by glargine U-100 and detemir, with the highest risk of hypoglycemia with Neutral Protamine Hagedorn (NPH) insulin (5).

**Patients with Compelling Need for Weight Loss**

Most patients with diabetes have obesity or overweight, and thus benefit from medications that promote weight loss. Two of the pillars of the AACE’s treatment approach to individuals with diabetes are lifestyle modifications including weight control, and avoiding weight gain. Both GLP-1 receptor agonists and SGLT-2 inhibitors can result in weight loss, although effects are generally greater for GLP-1 receptor agonists (5, 52). Liraglutide and semaglutide also have separate indications for weight loss regardless of diabetes status. In general, the degree of weight loss for semaglutide and liraglutide is greater than that of dulaglitude, which is greater than that of exenatide (5, 52). The combined GIP and GLP-1 agonist tirzepatide has shown even greater weight loss than that for GLP-1 receptor agonists (23, 25). In contrast, medications such as sulfonylureas, thiazolidinediones, and insulin tend to lead to weight gain (1, 5).

**Patients Where Cost is an Issue**

For many patients, cost can be a substantial barrier to care. Many patients are uninsured or underinsured. One in four patients on insulin report rationing their insulin doses due to cost (88). Patients should be asked about barriers to care. Often medication assistance programs and rebate programs can be used to decrease or eliminate the cost burden for patients. If these approaches are not successful, medications should be chosen keeping in mind the out-of-pocket cost for the patient. The cheapest medications are metformin, sulfonylureas, and thiazolidinediones. The typical approach, unless there are contraindications, is to start with metformin, then if additional agents are necessary to add sulfonylureas and then thiazolidinediones. If additional agents are needed, insulin can be added. Human insulins (regular, NPH) are cheaper than analogue insulins, and are discussed in the Insulin Therapy section.

## Insulin Therapy

For individuals with A1c > 9-10% with symptoms of hyperglycemia or catabolism, insulin therapy should be the initial treatment. Once the initial glucotoxicity has resolved, some individuals will be able to stop insulin, especially if they are able to make lifestyle modifications and achieve weight loss.

Individuals who are on maximal non-insulin therapy and still not at their goal A1c should have insulin initiated. Insulin should not be presented as a “threat” to patients. The natural history of type 2 diabetes should be discussed with patients, so that they understand that escalation of therapy and/or initiation of insulin are common, and do not represent a “failure” on the patient’s part.

If individuals are not already taking a GLP-1 receptor agonist, it should be considered prior to starting insulin. There are a number of insulin titration regimens that can be followed (1, 5). If cost is an issue, NPH and Regular insulin can be used. In patients with type 2 diabetes, insulin analogues do not always have a major advantage over human insulin products. Most studies comparing analogue insulins to human insulin products have not shown an improvement in glycemic control or reduced risk of severe hypoglycemia, although they do show reduced risk of overall and nocturnal hypoglycemia (89, 90).

A number of algorithms are available for insulin initiation and titration (1, 5). The key is to continue to adjust the insulin doses until the patient achieves their glycemic target. Typically, the patient is first started on basal insulin, and then the dose is gradually increased. The appropriateness of their preexisting diabetes medications should be evaluated when basal insulin is started. Most medications can be continued, but consideration can be given to stopping medications without cardiovascular, congestive heart failure, or renal benefit. Patients should be regularly assessed for “overbasalization.” Signs of overbasalization are shown in Table 10.

|  |
| --- |
| **Table 10. Signs of Overbasalization** |
| Basal dose > 0.5 IU/kg |
| Elevated bedtime-morning differential (> 50 mg/dL) |
| Elevated post-preprandial differential |
| Hypoglycemia |
| High glucose variability |

Adapted from American Diabetes Association (5)

At that point, prandial insulin should be initiated. If patients have a meal that is substantially larger than others (typically supper), prandial insulin can be started at the largest meal, and then additional doses added as needed. Most individuals with type 2 diabetes use a fixed prandial dose for meals, or a fixed dose with a correctional scale. However, individuals with highly variable meals or minimal insulin reserve (as assessed with a c-peptide measurement), using a carbohydrate to insulin ratio (as is done in type 1 diabetes) can be helpful. As with the initiation of basal insulin, when prandial insulin is initiated the patient’s preexisting diabetes regimen should be evaluated. In particular, sulfonylureas and meglitinides should be stopped when prandial insulin is added.

For patients where cost is an issue, human insulins can be more affordable than analogue insulins. In general, insulin doses should be decreased by 20% when switching from analogue insulin to human insulin in order to minimize the risk of hypoglycemia (89, 90).

The volume of insulin that can absorbed at a given time and given site can be a factor limiting insulin titration, especially as patients get to higher doses. For patients on over 200 units of insulin a day, switching to concentrated insulin formulations should be considered. In the past, U-500 regular insulin was the only option available. It has dose dependent pharmacokinetics, typically intermediate between regular and NPH insulin. In more recent years, U-200 degludec, U-300 glargine, and U-200 lispro have become available, and are often easier to use than U-500 regular insulin. While U-500 is available in vials and pens, if at all possible pens should be used, in order to reduce the chance of dosing errors.

Some individuals with type 2 diabetes on basal-bolus insulin regimens can benefit from an insulin pump (91, 92). Insurance coverage for insulin pumps for people with type 2 diabetes varies. When coupled with a CGM, some pumps allow for hybrid closed loop dosing, in which insulin doses are adjusted automatically based on current glucose values from the CGM.

**CONCLUSION**

Pharmacologic management of type 2 diabetes requires an individualized approach that weighs important factors such as efficacy, cost, side effects, adherence and treatment burden, comorbidities, mechanisms of action, and non-glycemic effects. Appropriate selection of medication can not only result in improved glucose control, but also have favorable effects on obesity, atherosclerotic cardiovascular disease, congestive heart failure, and chronic kidney disease.

**ACKNOWLEDGMENT**

Thank you to Tricia Santos Cavaiola MD and Jeremy H. Pettus MD, the previous authors of this chapter

# DISCLOSURES

E. Schroeder has no conflicts of interest to disclose.

**REFERENCES**

1. Garber AJ, Handelsman Y, Grunberger G, Einhorn D, Abrahamson MJ, Barzilay JI, et al. Consensus Statement by the American Association of Clinical Endocrinologists and American College of Endocrinology on the Comprehensive Type 2 Diabetes Management Algorithm - 2020 Executive Summary. Endocr Pract. 2020;26(1):107-39.

2. Handelsman Y, Bloomgarden ZT, Grunberger G, Umpierrez G, Zimmerman RS, Bailey TS, et al. American association of clinical endocrinologists and american college of endocrinology - clinical practice guidelines for developing a diabetes mellitus comprehensive care plan - 2015. Endocr Pract. 2015;21 Suppl 1:1-87.

3. Inzucchi SE, Bergenstal RM, Buse JB, Diamant M, Ferrannini E, Nauck M, et al. Management of hyperglycemia in type 2 diabetes, 2015: a patient-centered approach: update to a position statement of the American Diabetes Association and the European Association for the Study of Diabetes. Diabetes Care. 2015;38(1):140-9.

4. American Diabetes Association. 6. Glycemic Targets: Standards of Medical Care in Diabetes-2022. Diabetes Care. 2022;45(Suppl 1):S83-S96.

5. American Diabetes Association. 9. Pharmacologic Approaches to Glycemic Treatment: Standards of Medical Care in Diabetes-2022. Diabetes Care. 2022;45(Suppl 1):S125-S43.

6. American Diabetes Association. 13. Older Adults: Standards of Medical Care in Diabetes-2022. Diabetes Care. 2022;45(Suppl 1):S195-S207.

7. American Diabetes Association. 11. Chronic Kidney Disease and Risk Management: Standards of Medical Care in Diabetes-2022. Diabetes Care. 2022;45(Suppl 1):S175-S84.

8. American Diabetes Association. 10. Cardiovascular Disease and Risk Management: Standards of Medical Care in Diabetes-2022. Diabetes Care. 2022;45(Suppl 1):S144-S74.

9. Smith EM. Using continuous glucose monitoring in clinical practice. Clinical Diabetes. 2020;30(5):429-38.

10. Wright EE, Jr, Morgan K, Fu DK, Wilkins N, Guffey WJ. Time in range: how to measure it, how to report it, and its practical application in clinical decision-making. Clinical Diabetes. 2020;30(5):439-48.

11. Reddy N, Verma N, Dungan K. Monitoring Technologies - Continuous Glucose Monitoring, Mobile Technology, Biomarkers of Glycemic Control. In: Feingold KR, Anawalt B, Boyce A, Chrousos G, de Herder WW, Dhatariya K, et al., editors. Endotext [Internet]. South Dartmouth (MA): MDText.com, Inc.; 2020.

12. American Diabetes Association. Summary of Revisions: Standards of Medical Care in Diabetes-2021. Diabetes Care. 2021;44(Suppl 1):S4-S6.

13. Duckworth WC, Abraira C, Moritz TE, Davis SN, Emanuele N, Goldman S, et al. The duration of diabetes affects the response to intensive glucose control in type 2 subjects: the VA Diabetes Trial. J Diabetes Complications. 2011;25(6):355-61.

14. Action to Control Cardiovascular Risk in Diabetes Study Group, Gerstein HC, Miller ME, Byington RP, Goff DC, Jr., Bigger JT, et al. Effects of intensive glucose lowering in type 2 diabetes. N Engl J Med. 2008;358(24):2545-59.

15. Ismail-Beigi F, Craven T, Banerji MA, Basile J, Calles J, Cohen RM, et al. Effect of intensive treatment of hyperglycaemia on microvascular outcomes in type 2 diabetes: an analysis of the ACCORD randomised trial. Lancet. 2010;376(9739):419-30.

16. Group AC, Patel A, MacMahon S, Chalmers J, Neal B, Billot L, et al. Intensive blood glucose control and vascular outcomes in patients with type 2 diabetes. N Engl J Med. 2008;358(24):2560-72.

17. Skyler JS, Bergenstal R, Bonow RO, Buse J, Deedwania P, Gale EA, et al. Intensive glycemic control and the prevention of cardiovascular events: implications of the ACCORD, ADVANCE, and VA diabetes trials: a position statement of the American Diabetes Association and a scientific statement of the American College of Cardiology Foundation and the American Heart Association. Diabetes Care. 2009;32(1):187-92.

18. Lash RW, Lucas DO, Illes J. Preventing Hypoglycemia in Type 2 Diabetes. J Clin Endocrinol Metab. 2018;103(4):1265-8.

19. Edridge CL, Dunkley AJ, Bodicoat DH, Rose TC, Gray LJ, Davies MJ, et al. Prevalence and Incidence of Hypoglycaemia in 532,542 People with Type 2 Diabetes on Oral Therapies and Insulin: A Systematic Review and Meta-Analysis of Population Based Studies. PLoS One. 2015;10(6):e0126427.

20. Centers for Disease Control and Prevention. National Diabetes Statistics Report 2020: Estimates of Diabetes and Its Burden in the United States 2020 [Available from: <https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf>.

21. Lipska KJ, Ross JS, Wang Y, Inzucchi SE, Minges K, Karter AJ, et al. National trends in US hospital admissions for hyperglycemia and hypoglycemia among Medicare beneficiaries, 1999 to 2011. JAMA Intern Med. 2014;174(7):1116-24.

22. Rosenstock J, Wysham C, Frias JP, Kaneko S, Lee CJ, Fernandez Lando L, et al. Efficacy and safety of a novel dual GIP and GLP-1 receptor agonist tirzepatide in patients with type 2 diabetes (SURPASS-1): a double-blind, randomised, phase 3 trial. Lancet. 2021;398(10295):143-55.

23. Frias JP, Davies MJ, Rosenstock J, Perez Manghi FC, Fernandez Lando L, Bergman BK, et al. Tirzepatide versus Semaglutide Once Weekly in Patients with Type 2 Diabetes. N Engl J Med. 2021;385(6):503-15.

24. Ludvik B, Giorgino F, Jodar E, Frias JP, Fernandez Lando L, Brown K, et al. Once-weekly tirzepatide versus once-daily insulin degludec as add-on to metformin with or without SGLT2 inhibitors in patients with type 2 diabetes (SURPASS-3): a randomised, open-label, parallel-group, phase 3 trial. Lancet. 2021;398(10300):583-98.

25. Del Prato S, Kahn SE, Pavo I, Weerakkody GJ, Yang Z, Doupis J, et al. Tirzepatide versus insulin glargine in type 2 diabetes and increased cardiovascular risk (SURPASS-4): a randomised, open-label, parallel-group, multicentre, phase 3 trial. Lancet. 2021;398(10313):1811-24.

26. Dahl D, Onishi Y, Norwood P, Huh R, Bray R, Patel H, et al. Effect of Subcutaneous Tirzepatide vs Placebo Added to Titrated Insulin Glargine on Glycemic Control in Patients With Type 2 Diabetes: The SURPASS-5 Randomized Clinical Trial. JAMA. 2022;327(6):534-45.

27. Feingold KR. Oral and Injectable (Non-Insulin) Pharmacological Agents for the Treatment of Type 2 Diabetes. In: Feingold KR, Anawalt B, Boyce A, Chrousos G, de Herder WW, Dhatariya K, et al., editors. Endotext [Internet]. South Dartmouth (MA): MDText.com, Inc.; 2021.

28. Donner T, Sarkar S. Insulin - Pharmacology, Therapeutic Regimens and Principles of Intensive Insulin Therapy. In: Feingold KR, Anawalt B, Boyce A, Chrousos G, de Herder WW, Dhatariya K, et al., editors. Endotext [Internet]. South Dartmouth (MA): MDText.com, Inc.; 2019.

29. White JR, Jr. A Brief History of the Development of Diabetes Medications. Diabetes Spectr. 2014;27(2):82-6.

30. Defronzo RA. Banting Lecture. From the triumvirate to the ominous octet: a new paradigm for the treatment of type 2 diabetes mellitus. Diabetes. 2009;58(4):773-95.

31. Ferrannini E, DeFronzo RA. Impact of glucose-lowering drugs on cardiovascular disease in type 2 diabetes. Eur Heart J. 2015;36(34):2288-96.

32. Schwartz SS, Epstein S, Corkey BE, Grant SF, Gavin JR, 3rd, Aguilar RB. The Time Is Right for a New Classification System for Diabetes: Rationale and Implications of the beta-Cell-Centric Classification Schema. Diabetes Care. 2016;39(2):179-86.

33. American Association of Clinical Endocrinologists. American Association of Clinical Endocrinologists and American College of Endocrinology Clinical Practice Guidelines for Developing a Diabetes Mellitus Comprehensive Care Plan Slideshow 2015 [Available from: <https://pro.aace.com/disease-state-resources/diabetes/clinical-practice-guidelines/aaceace-clinical-practice-guidelines>.

34. Khunti K, Seidu S. Therapeutic Inertia and the Legacy of Dysglycemia on the Microvascular and Macrovascular Complications of Diabetes. Diabetes Care. 2019;42(3):349-51.

35. Gabbay RA, Kendall D, Beebe C, Cuddeback J, Hobbs T, Khan ND, et al. Addressing Therapeutic Inertia in 2020 and Beyond: A 3-Year Initiative of the American Diabetes Association. Clin Diabetes. 2020;38(4):371-81.

36. Mauricio D, Meneghini L, Seufert J, Liao L, Wang H, Tong L, et al. Glycaemic control and hypoglycaemia burden in patients with type 2 diabetes initiating basal insulin in Europe and the USA. Diabetes Obes Metab. 2017;19(8):1155-64.

37. Abdul-Ghani MA, Puckett C, Triplitt C, Maggs D, Adams J, Cersosimo E, et al. Initial combination therapy with metformin, pioglitazone and exenatide is more effective than sequential add-on therapy in subjects with new-onset diabetes. Results from the Efficacy and Durability of Initial Combination Therapy for Type 2 Diabetes (EDICT): a randomized trial. Diabetes Obes Metab. 2015;17(3):268-75.

38. Lipska KJ, Ross JS, Miao Y, Shah ND, Lee SJ, Steinman MA. Potential overtreatment of diabetes mellitus in older adults with tight glycemic control. JAMA Intern Med. 2015;175(3):356-62.

39. Hambling CE, Seidu SI, Davies MJ, Khunti K. Older people with Type 2 diabetes, including those with chronic kidney disease or dementia, are commonly overtreated with sulfonylurea or insulin therapies. Diabet Med. 2017;34(9):1219-27.

40. Okemah J, Peng J, Quinones M. Addressing Clinical Inertia in Type 2 Diabetes Mellitus: A Review. Adv Ther. 2018;35(11):1735-45.

41. Davies MJ, D'Alessio DA, Fradkin J, Kernan WN, Mathieu C, Mingrone G, et al. Management of Hyperglycemia in Type 2 Diabetes, 2018. A Consensus Report by the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD). Diabetes Care. 2018;41(12):2669-701.

42. Cosentino F, Grant PJ, Aboyans V, Bailey CJ, Ceriello A, Delgado V, et al. 2019 ESC Guidelines on diabetes, pre-diabetes, and cardiovascular diseases developed in collaboration with the EASD. Eur Heart J. 2020;41(2):255-323.

43. Cooke D, Bond R, Lawton J, Rankin D, Heller S, Clark M, et al. Structured type 1 diabetes education delivered within routine care: impact on glycemic control and diabetes-specific quality of life. Diabetes Care. 2013;36(2):270-2.

44. Cochran J, Conn VS. Meta-analysis of quality of life outcomes following diabetes self-management training. Diabetes Educ. 2008;34(5):815-23.

45. He X, Li J, Wang B, Yao Q, Li L, Song R, et al. Diabetes self-management education reduces risk of all-cause mortality in type 2 diabetes patients: a systematic review and meta-analysis. Endocrine. 2017;55(3):712-31.

46. Robbins JM, Thatcher GE, Webb DA, Valdmanis VG. Nutritionist visits, diabetes classes, and hospitalization rates and charges: the Urban Diabetes Study. Diabetes Care. 2008;31(4):655-60.

47. Duncan I, Ahmed T, Li QE, Stetson B, Ruggiero L, Burton K, et al. Assessing the value of the diabetes educator. Diabetes Educ. 2011;37(5):638-57.

48. Strawbridge LM, Lloyd JT, Meadow A, Riley GF, Howell BL. One-Year Outcomes of Diabetes Self-Management Training Among Medicare Beneficiaries Newly Diagnosed With Diabetes. Med Care. 2017;55(4):391-7.

49. American Diabetes A. 5. Facilitating Behavior Change and Well-being to Improve Health Outcomes: Standards of Medical Care in Diabetes-2022. Diabetes Care. 2022;45(Suppl 1):S60-S82.

50. Lean MEJ, Leslie WS, Barnes AC, Brosnahan N, Thom G, McCombie L, et al. Durability of a primary care-led weight-management intervention for remission of type 2 diabetes: 2-year results of the DiRECT open-label, cluster-randomised trial. Lancet Diabetes Endocrinol. 2019;7(5):344-55.

51. Garvey WT, Garber AJ, Mechanick JI, Bray GA, Dagogo-Jack S, Einhorn D, et al. American association of clinical endocrinologists and american college of endocrinology position statement on the 2014 advanced framework for a new diagnosis of obesity as a chronic disease. Endocr Pract. 2014;20(9):977-89.

52. American Diabetes Association. 8. Obesity and Weight Management for the Prevention and Treatment of Type 2 Diabetes: Standards of Medical Care in Diabetes-2022. Diabetes Care. 2022;45(Suppl 1):S113-S24.

53. American Diabetes Association. 5. Facilitating Behavior Change and Well-being to Improve Health Outcomes: Standards of Medical Care in Diabetes-2021. Diabetes Care. 2021;44(Suppl 1):S53-S72.

54. American Diabetes Association. Summary of Revisions: Standards of Medical Care in Diabetes-2022. Diabetes Care. 2022;45(Suppl 1):S8-S16.

55. Kahn SE, Haffner SM, Heise MA, Herman WH, Holman RR, Jones NP, et al. Glycemic durability of rosiglitazone, metformin, or glyburide monotherapy. N Engl J Med. 2006;355(23):2427-43.

56. Maruthur NM, Tseng E, Hutfless S, Wilson LM, Suarez-Cuervo C, Berger Z, et al. Diabetes Medications as Monotherapy or Metformin-Based Combination Therapy for Type 2 Diabetes: A Systematic Review and Meta-analysis. Ann Intern Med. 2016;164(11):740-51.

57. Flory JH, Mushlin AI. Effect of Cost and Formulation on Persistence and Adherence to Initial Metformin Therapy for Type 2 Diabetes. Diabetes Care. 2020;43(6):e66-e7.

58. U.S. Food and Drug Administration. FDA Drug Safety Communication: FDA revises warnings regarding use of the diabetes medicine metformin in certain patients with reduced kidney function 2016 [Available from: <https://www.fda.gov/drugs/drug-safety-and-availability/fda-drug-safety-communication-fda-revises-warnings-regarding-use-diabetes-medicine-metformin-certain>.

59. Lipska KJ, Bailey CJ, Inzucchi SE. Use of metformin in the setting of mild-to-moderate renal insufficiency. Diabetes Care. 2011;34(6):1431-7.

60. Inzucchi SE, Lipska KJ, Mayo H, Bailey CJ, McGuire DK. Metformin in patients with type 2 diabetes and kidney disease: a systematic review. JAMA. 2014;312(24):2668-75.

61. Lalau JD, Kajbaf F, Bennis Y, Hurtel-Lemaire AS, Belpaire F, De Broe ME. Metformin Treatment in Patients With Type 2 Diabetes and Chronic Kidney Disease Stages 3A, 3B, or 4. Diabetes Care. 2018;41(3):547-53.

62. Kidney Disease: Improving Global Outcomes Diabetes Work G. KDIGO 2020 Clinical Practice Guideline for Diabetes Management in Chronic Kidney Disease. Kidney Int. 2020;98(4S):S1-S115.

63. Aroda VR, Edelstein SL, Goldberg RB, Knowler WC, Marcovina SM, Orchard TJ, et al. Long-term Metformin Use and Vitamin B12 Deficiency in the Diabetes Prevention Program Outcomes Study. J Clin Endocrinol Metab. 2016;101(4):1754-61.

64. Marso SP, Daniels GH, Brown-Frandsen K, Kristensen P, Mann JF, Nauck MA, et al. Liraglutide and Cardiovascular Outcomes in Type 2 Diabetes. N Engl J Med. 2016;375(4):311-22.

65. Marso SP, Bain SC, Consoli A, Eliaschewitz FG, Jodar E, Leiter LA, et al. Semaglutide and Cardiovascular Outcomes in Patients with Type 2 Diabetes. N Engl J Med. 2016;375(19):1834-44.

66. Gerstein HC, Colhoun HM, Dagenais GR, Diaz R, Lakshmanan M, Pais P, et al. Dulaglutide and cardiovascular outcomes in type 2 diabetes (REWIND): a double-blind, randomised placebo-controlled trial. Lancet. 2019;394(10193):121-30.

67. Zinman B, Wanner C, Lachin JM, Fitchett D, Bluhmki E, Hantel S, et al. Empagliflozin, Cardiovascular Outcomes, and Mortality in Type 2 Diabetes. N Engl J Med. 2015;373(22):2117-28.

68. Neal B, Perkovic V, Matthews DR. Canagliflozin and Cardiovascular and Renal Events in Type 2 Diabetes. N Engl J Med. 2017;377(21):2099.

69. Perkovic V, Jardine MJ, Neal B, Bompoint S, Heerspink HJL, Charytan DM, et al. Canagliflozin and Renal Outcomes in Type 2 Diabetes and Nephropathy. N Engl J Med. 2019;380(24):2295-306.

70. Wiviott SD, Raz I, Bonaca MP, Mosenzon O, Kato ET, Cahn A, et al. Dapagliflozin and Cardiovascular Outcomes in Type 2 Diabetes. N Engl J Med. 2019;380(4):347-57.

71. Heerspink HJL, Stefansson BV, Correa-Rotter R, Chertow GM, Greene T, Hou FF, et al. Dapagliflozin in Patients with Chronic Kidney Disease. N Engl J Med. 2020;383(15):1436-46.

72. McMurray JJV, Solomon SD, Inzucchi SE, Kober L, Kosiborod MN, Martinez FA, et al. Dapagliflozin in Patients with Heart Failure and Reduced Ejection Fraction. N Engl J Med. 2019;381(21):1995-2008.

73. Cannon CP, Pratley R, Dagogo-Jack S, Mancuso J, Huyck S, Masiukiewicz U, et al. Cardiovascular Outcomes with Ertugliflozin in Type 2 Diabetes. N Engl J Med. 2020;383(15):1425-35.

74. Packer M, Anker SD, Butler J, Filippatos G, Pocock SJ, Carson P, et al. Cardiovascular and Renal Outcomes with Empagliflozin in Heart Failure. N Engl J Med. 2020;383(15):1413-24.

75. Wheeler DC, Stefansson BV, Batiushin M, Bilchenko O, Cherney DZI, Chertow GM, et al. The dapagliflozin and prevention of adverse outcomes in chronic kidney disease (DAPA-CKD) trial: baseline characteristics. Nephrol Dial Transplant. 2020;35(10):1700-11.

76. Cannon CP, McGuire DK, Pratley R, Dagogo-Jack S, Mancuso J, Huyck S, et al. Design and baseline characteristics of the eValuation of ERTugliflozin effIcacy and Safety CardioVascular outcomes trial (VERTIS-CV). Am Heart J. 2018;206:11-23.

77. Neuen BL, Ohkuma T, Neal B, Matthews DR, de Zeeuw D, Mahaffey KW, et al. Cardiovascular and Renal Outcomes With Canagliflozin According to Baseline Kidney Function. Circulation. 2018;138(15):1537-50.

78. Bakris GL. Major Advancements in Slowing Diabetic Kidney Disease Progression: Focus on SGLT2 Inhibitors. Am J Kidney Dis. 2019;74(5):573-5.

79. Mahaffey KW, Neal B, Perkovic V, de Zeeuw D, Fulcher G, Erondu N, et al. Canagliflozin for Primary and Secondary Prevention of Cardiovascular Events: Results From the CANVAS Program (Canagliflozin Cardiovascular Assessment Study). Circulation. 2018;137(4):323-34.

80. Mahaffey KW, Jardine MJ, Bompoint S, Cannon CP, Neal B, Heerspink HJL, et al. Canagliflozin and Cardiovascular and Renal Outcomes in Type 2 Diabetes Mellitus and Chronic Kidney Disease in Primary and Secondary Cardiovascular Prevention Groups. Circulation. 2019;140(9):739-50.

81. Jardine MJ, Mahaffey KW, Neal B, Agarwal R, Bakris GL, Brenner BM, et al. The Canagliflozin and Renal Endpoints in Diabetes with Established Nephropathy Clinical Evaluation (CREDENCE) Study Rationale, Design, and Baseline Characteristics. Am J Nephrol. 2017;46(6):462-72.

82. Heerspink HJ, Desai M, Jardine M, Balis D, Meininger G, Perkovic V. Canagliflozin Slows Progression of Renal Function Decline Independently of Glycemic Effects. J Am Soc Nephrol. 2017;28(1):368-75.

83. Gerstein HC, Sattar N, Rosenstock J, Ramasundarahettige C, Pratley R, Lopes RD, et al. Cardiovascular and Renal Outcomes with Efpeglenatide in Type 2 Diabetes. N Engl J Med. 2021;385(10):896-907.

84. Novo Nordisk. Saxenda Prescribing Information 2020 [Available from: <https://www.novo-pi.com/saxenda.pdf>.

85. Novo Nordisk. Wegovy Prescribing Information 2021 [Available from: <https://www.novo-pi.com/wegovy.pdf>.

86. AstraZeneca Pharmaceuticals. Farxiga Prescribing Information 2021 [Available from: <https://den8dhaj6zs0e.cloudfront.net/50fd68b9-106b-4550-b5d0-12b045f8b184/0be9cb1b-3b33-41c7-bfc2-04c9f718e442/0be9cb1b-3b33-41c7-bfc2-04c9f718e442_viewable_rendition__v.pdf>.

87. Boehringer Ingelheim Pharmaceuticals. Jardiance Prescribing Information 2021 [Available from: <https://docs.boehringer-ingelheim.com/Prescribing%20Information/PIs/Jardiance/jardiance.pdf>.

88. Herkert D, Vijayakumar P, Luo J, Schwartz JI, Rabin TL, DeFilippo E, et al. Cost-Related Insulin Underuse Among Patients With Diabetes. JAMA Intern Med. 2019;179(1):112-4.

89. Lipska KJ, Hirsch IB, Riddle MC. Human Insulin for Type 2 Diabetes: An Effective, Less-Expensive Option. JAMA. 2017;318(1):23-4.

90. Lipska KJ. Insulin Analogues for Type 2 Diabetes. JAMA. 2019;321(4):350-1.

91. Grunberger G, Sherr J, Allende M, Blevins T, Bode B, Handelsman Y, et al. American Association of Clinical Endocrinology Clinical Practice Guideline: The Use of Advanced Technology in the Management of Persons With Diabetes Mellitus. Endocr Pract. 2021;27(6):505-37.

92. American Diabetes Association. 7. Diabetes Technology: Standards of Medical Care in Diabetes-2022. Diabetes Care. 2022;45(Suppl 1):S97-S112.