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;38:140–149 | DOI: 10.2337/dc14-2441

In 2012, the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD) published a position statement on the management of hyperglycemia in patients with type 2 diabetes (1,2). This was needed because of an increasing array of antihyperglycemic drugs and growing uncertainty regarding their proper selection and sequence. Because of a paucity of comparative effectiveness research on long-term treatment outcomes with many of these medications, the 2012 publication was less prescriptive than prior consensus reports. We previously described the need to individualize both treatment targets and treatment strategies, with an emphasis on patient-centered care and shared decision making, and this continues to be our position, although there are now more head-to-head trials that show slight variance between agents with regard to glucose-lowering effects. Nevertheless, these differences are often small and would be unlikely to reflect any definite differential effect in an individual patient.

The ADA and EASD have requested an update to the position statement incorporating new data from recent clinical trials. Between June and September of 2014, the Writing Group reconvened, including one face-to-face meeting, to discuss the changes. An entirely new statement was felt to be unnecessary. Instead, the group focused on those areas where revisions were suggested by a changing evidence base. This briefer article should therefore be read as an addendum to the previous full account (1,2).

GLYCEMIC TARGETS

Glucose control remains a major focus in the management of patients with type 2 diabetes. However, this should always be in the context of a comprehensive cardiovascular risk factor reduction program, to include smoking cessation and the adoption of other healthy lifestyle habits, blood pressure control, lipid management with priority to statin medications, and, in some circumstances, antiplatelet therapy. Studies have conclusively determined that reducing hyperglycemia decreases the onset and progression of microvascular complications (3,4). The impact of glucose control on cardiovascular complications remains uncertain; a more modest benefit is likely to be present, but probably emerges only after many years of improved control (5). Results from large trials have also suggested that overly aggressive control in older patients with more advanced disease may not have significant benefits and may indeed present some risk (6). Accordingly, instead of a one-size-fits-all approach, personalization is necessary, balancing the benefits of glycemic control with its potential risks, taking into account the adverse effects of glucose-lowering medications (particularly hypoglycemia), and the patient’s age and health status, among other concerns. Figure 1 displays those patient and disease factors that may influence the target for glucose control, as reflected by HbA1c. The main update to this figure is the separation of those factors that are potentially modifiable from those that are usually not. The patient’s attitude and expected treatment efforts and access to resources and support systems are unique in so
Side effects of SGLT2 inhibitor therapy include genital mycotic infections, at rates of about 11% higher in women and about 4% higher in men compared with placebo (17); in some studies, a slight increase in urinary tract infections was shown (7,9,12,17,18). They also possess a diuretic effect, and so symptoms related to volume depletion may occur (7,19). Consequently, these agents should be used cautiously in the elderly, in any patient already on a diuretic, and in anyone with a tenuous intravascular volume status. Reversible small increases in serum creatinine occur (14,19). Increased urine calcium excretion has been observed (20), and the U.S. Food and Drug Administration (FDA) mandated a follow-up of upper limb fractures of patients on canagliflozin after an adverse imbalance in cases was reported in short-term trials (21). Small increases in LDL cholesterol (−5%) have been noted in some trials, the implications of which are unknown. Due to their mechanism of action, SGLT2 inhibitors are less effective when the estimated GFR (eGFR) is \(<45–60 \text{ mL/min/1.73 m}^2\); currently available agents have variable label restrictions for values below this threshold.

Data on microvascular outcomes with SGLT2 inhibitors are lacking (as with most agents other than sulfonylureas and insulin). Effects on macrovascular disease are also unknown; cardiovascular safety trials are currently in progress (22).

**Thiazolidinediones**

Earlier concerns that the thiazolidinediones (TZDs)—in particular pioglitazone—are associated with bladder cancer have largely been alloyed by subsequent evidence (23–25). These agents tend to cause weight gain and peripheral edema and have been shown to increase the incidence of heart failure (26). They also increase the risk of bone fractures, predominately in women (27). Pioglitazone is now available as a generic drug, substantially decreasing its cost.
Table 1—Properties of available glucose-lowering agents in the U.S. and Europe that may guide individualized treatment choices in patients with type 2 diabetes

<table>
<thead>
<tr>
<th>Class</th>
<th>Compound(s)</th>
<th>Cellular mechanism(s)</th>
<th>Primary physiological action(s)</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Cost*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biguanides</td>
<td>Metformin</td>
<td>Activates AMP-kinase (≠ other)</td>
<td>↓ Hepatic glucose production</td>
<td>Extensive experience</td>
<td>Gastrointestinal side effects (diarrhea, abdominal cramping)</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No hypoglycemia</td>
<td>Lactic acidosis risk (rare)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>↓ CVD events (UKPDS)</td>
<td>Vitamin B12 deficiency</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Multiple contraindications: CKD, acidosis, hypoxia, dehydration, etc.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>↓ CVD events (UKPDS)</td>
<td></td>
</tr>
<tr>
<td>Sulfonylureas</td>
<td>2nd Generation</td>
<td>Closes K_{ATP} channels on β-cell plasma membranes</td>
<td>↑ Insulin secretion</td>
<td>Extensive experience</td>
<td>Hypoglycemia</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Glyburide/glibenclamide</td>
<td></td>
<td></td>
<td>↓ Microvascular risk (UKPDS)</td>
<td>Weight</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Glipizide</td>
<td></td>
<td></td>
<td></td>
<td>? Blunts myocardial ischemic preconditioning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gliclazide†</td>
<td></td>
<td></td>
<td></td>
<td>Low durability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Glimepiride</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meglitinides (glinides)</td>
<td>Repaglinide</td>
<td>Closes K_{ATP} channels on β-cell plasma membranes</td>
<td>↑ Insulin secretion</td>
<td>↓ Postprandial glucose excursions</td>
<td>Hypoglycemia</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Nateglinide</td>
<td></td>
<td></td>
<td>Dosing flexibility</td>
<td>Weight</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>? Blunts myocardial ischemic preconditioning</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Frequent dosing schedule</td>
<td></td>
</tr>
<tr>
<td>TZDs</td>
<td>Pioglitazone†</td>
<td>Activates the nuclear transcription factor PPAR-γ</td>
<td>↑ Insulin sensitivity</td>
<td>No hypoglycemia</td>
<td>Edema/heart failure</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Rosiglitazone§</td>
<td></td>
<td></td>
<td>Durability</td>
<td>Bone fractures</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>↑ HDL-C</td>
<td>↑ Triglycerides (pioglitazone)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>↓ CVD events (PROactive, pioglitazone)</td>
<td>↑ MI (meta-analyses, rosiglitazone)</td>
<td></td>
</tr>
<tr>
<td>α-Glucosidase inhibitors</td>
<td>Acarbose</td>
<td>Inhibits intestinal α-glucosidase</td>
<td>Slows intestinal carbohydrate digestion/absorption</td>
<td>No hypoglycemia</td>
<td>Generally modest HbA1c efficacy</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Miglitol</td>
<td></td>
<td></td>
<td>↓ Postprandial glucose excursions</td>
<td>Gas trointestinal side effects (flatulence, diarrhea)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>↑ CVD events (STOP-NIDDM)</td>
<td>Frequency dosing schedule</td>
<td></td>
</tr>
<tr>
<td>DPP-4 inhibitors</td>
<td>Sitagliptin</td>
<td>Inhibits DPP-4 activity, increasing postprandial active incretin (GLP-1, GIP) concentrations</td>
<td>↑ Insulin secretion (glucose-dependent)</td>
<td>No hypoglycemia</td>
<td>Angioedema/urticaria and other immune-mediated dermatological effects</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Vildagliptin†</td>
<td></td>
<td></td>
<td>↓ Glucagon secretion (glucose-dependent)</td>
<td>Acute pancreatitis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Saxagliptin</td>
<td></td>
<td></td>
<td></td>
<td>? ↑ Heart failure hospitalizations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Linagliptin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alogliptin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bile acid sequestrants</td>
<td>Colesevelam</td>
<td>Binds bile acids in intestinal tract, increasing hepatic bile acid production</td>
<td>↑ Hepatic glucose production</td>
<td>No hypoglycemia</td>
<td>Generally modest HbA1c efficacy</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>↓ LDL-C</td>
<td>Constipation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>↑ Triglycerides</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>May ↓ absorption of other medications</td>
<td></td>
</tr>
</tbody>
</table>

Continued on p. 143
### Table 1—Continued

<table>
<thead>
<tr>
<th>Class</th>
<th>Compound(s)</th>
<th>Cellular mechanism(s)</th>
<th>Primary physiological action(s)</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Cost*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dopamine-2 agonists</td>
<td>• Bromocriptine (quick release)§</td>
<td>Activates dopaminergic receptors</td>
<td>• Modulates hypothalamic regulation of metabolism</td>
<td>• No hypoglycemia</td>
<td>• Generally modest HbA1c efficacy</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• ↑ Insulin sensitivity</td>
<td>• ↓ CVD events (Cycloset Safety Trial)</td>
<td>• Dizziness/syncope</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Nausea</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Fatigue</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Rhinitis</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>SGLT2 inhibitors</strong></td>
<td>Inhibits SGLT2 in the proximal nephron</td>
<td>• Blocks glucose reabsorption by the kidney, increasing glucosuria</td>
<td>• No hypoglycemia</td>
<td>• Genitourinary infections</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>• Canagliflozin</td>
<td></td>
<td></td>
<td></td>
<td>• Polyuria</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Dapagliflozin‡</td>
<td></td>
<td></td>
<td></td>
<td>• Volume depletion/hypotension/dizziness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Empagliflozin</td>
<td></td>
<td></td>
<td></td>
<td>• ↑ LDL-C</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>GLP-1 receptor agonists</strong></td>
<td>Activates GLP-1 receptors</td>
<td>• ↑ Insulin secretion (glucose-dependent)</td>
<td>• No hypoglycemia</td>
<td>• Gastrointestinal side effects (nausea/vomiting/diarrhea)</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>• Exenatide</td>
<td></td>
<td>• ↓ Glucagon secretion (glucose-dependent)</td>
<td>• ↓ Weight</td>
<td>• ↑ Heart rate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Exenatide extended release</td>
<td></td>
<td>• Slows gastric emptying</td>
<td>• ↑ Postprandial glucose excursions</td>
<td>• ↑ Acute pancreatitis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Liraglutide</td>
<td></td>
<td></td>
<td>• Slows gastric emptying</td>
<td>• C-cell hyperplasia/medullary thyroid tumors in animals</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Albiglutide</td>
<td></td>
<td></td>
<td></td>
<td>• Injectable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Lixisenatide†</td>
<td></td>
<td></td>
<td></td>
<td>• Training requirements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Dulaglutide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amylin mimetics</td>
<td>• Pramlintide§</td>
<td>Activates amylin receptors</td>
<td>• ↓ Glucagon secretion</td>
<td>• ↓ Postprandial glucose excursions</td>
<td>• Generally modest HbA1c efficacy</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Slows gastric emptying</td>
<td>• ↓ Weight</td>
<td>• Gastrointestinal side effects (nausea/vomiting)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• ↑ Satiety</td>
<td></td>
<td>• Hypoglycemia</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Unless insulin dose is simultaneously reduced</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Injectable</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Frequent dosing schedule</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Training requirements</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Insulins</strong></td>
<td>Activates insulin receptors</td>
<td>• ↑ Glucose disposal</td>
<td>• Nearly universal response</td>
<td>• Hypoglycemia</td>
<td>Variable#</td>
</tr>
<tr>
<td></td>
<td>• Rapid-acting analogs</td>
<td></td>
<td>• ↓ Hepatic glucose production</td>
<td>• Theoretically unlimited efficacy</td>
<td>• Weight gain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Lispro</td>
<td></td>
<td>• Other</td>
<td>• ↓ Microvascular risk (UKPDS)</td>
<td>• Mitogenic effects</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Aspart</td>
<td></td>
<td></td>
<td></td>
<td>• Injectable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Glulisine</td>
<td></td>
<td></td>
<td></td>
<td>• Training requirements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Short-acting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Human Regular</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Intermediate-acting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Human NPH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Basal insulin analogs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Glargine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Detemir</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Degludec</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Premixed (several types)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CVD, cardiovascular disease; GIP, glucose-dependent insulinotropic peptide; HDL-C, HDL cholesterol; LDL-C, LDL cholesterol; MI, myocardial infarction; PPAR-γ, peroxisome proliferator–activated receptor γ; PROactive, Prospective Pioglitazone Clinical Trial in Macrovascular Events (26); STOP-NIDDM, Study to Prevent Non-Insulin-Dependent Diabetes Mellitus (60); T2DM, type 2 diabetes mellitus; UKPDS, UK Prospective Diabetes Study (4,61). Cycloset trial of quick-release bromocriptine (62). *Cost is based on lowest-priced member of the class (see Supplementary Data). †Not licensed in the U.S. Initial concerns regarding bladder cancer risk are decreasing after subsequent study. §Not licensed in Europe for type 2 diabetes. #Cost is highly dependent on type/brand (analogics > human insulins) and dosage.
Alogliptin, another DPP-4 inhibitor, also did not have any demonstrable cardiovascular excess risk over an even shorter period (18 months) in high-risk patients (30). A wider database interrogation indicated no signal for cardiovascular disease or heart failure (30,31). Several other trials are underway, and until the results of these are reported, this class should probably be used cautiously, if at all, in patients with preexisting heart failure.

One area of concern with this class, as well as the other incretin-based category, the glucagon-like peptide 1 (GLP-1) receptor agonists, has been pancreatic safety—both regarding possible pancreatitis and pancreatic neoplasia. The prescribing guidelines for these drugs include cautions about using them in individuals with a prior history of pancreatitis. While this is reasonable, emerging data from large observational data sets (32), as well as from two large cardiovascular trials with DPP-4 inhibitors (28–30), have found no statistically increased rates of pancreatic disease.

Generally speaking, the use of any drug in patients with type 2 diabetes must balance the glucose-lowering efficacy, side-effect profiles, anticipation of additional benefits, cost, and other practical aspects of care, such as dosing schedule and requirements for glucose monitoring. The patient—who is obviously the individual most affected by drug choice—should participate in a shared decision-making process regarding both the intensiveness of blood glucose control and which medications are to be selected.

IMPLEMENTATION STRATEGIES

Initial Drug Therapy (See Fig. 2)

Metformin remains the optimal drug for monotherapy. Its low cost, proven safety record, weight neutrality, and possible benefits on cardiovascular outcomes have secured its place as the favored initial drug choice. There is increasing evidence that the current cut-off points for renal safety in the U.S. (contraindicated if serum creatinine \( \geq 1.5 \) mg/dL [\( \geq 133 \mu mol/L \) in men or 1.4 mg/dL (124 \( \mu mol/L \) in women] may be overly restrictive (33). Accordingly, there are calls to relax prescribing policies to extend the use of this important medication to those with mild–moderate, but stable, chronic kidney disease (CKD) (34–36). Many practitioners would continue to prescribe metformin even when the eGFR falls to less than 45–60 mL/min/1.73 m², perhaps with dose adjustments to account for reduced renal clearance of the compound. One criterion for stopping the drug is an eGFR of <30 mL/min/1.73 m² (34,37,38). Of course, any use in patients with CKD mandates diligent follow-up of renal function.

In circumstances where metformin is contraindicated or not tolerated, one of the second-line agents (see below) may be used, although the choices become more limited if renal insufficiency is the reason metformin is being avoided. In these circumstances it is unwise to use sulfonylureas, particularly glyburide (known as glibenclamide in Europe), because of the risk of hypoglycemia. DPP-4 inhibitors are probably a preferable choice, although, with the exception of linagliptin (39), dosage adjustments are required.

Advancing to Dual Combination and Triple Combination Therapy (See Fig. 2)

While the SGLT2 inhibitors are approved as monotherapy, they are mainly used in combination with metformin and/or other agents (19). Given their demonstrated efficacy and clinical experience to date, they are reasonable options as second-line or third-line agents (40–42) (Fig. 2). Similar to most combinations, efficacy may be less than additive when SGLT2 inhibitors are used in combination with DPP-4 inhibitors (43). There are no data available on the use of SGLT2 inhibitors in conjunction with GLP-1 receptor agonists; an evidence-based recommendation for this combination cannot be made at this time.

As noted in the original position statement, initial combination therapy with metformin plus a second agent may allow patients to achieve HbA₁c targets more quickly than sequential therapy. Accordingly, such an approach may be considered in those individuals with baseline HbA₁c levels well above target, who are unlikely to successfully attain their goal using monotherapy. A reasonable threshold HbA₁c for this consideration is \( \geq 9\% \) (\( \geq 75 \) mmol/mol). Of course, there is no proven overall advantage to achieving a glycemic target more quickly by a matter of weeks or even months. Accordingly, as long as close patient follow-up can be ensured, prompt sequential therapy is a reasonable alternative, even in those with baseline HbA₁c levels in this range.

Combination Injectable Therapy (See Figs. 2 and 3)

In certain patients, glucose control remains poor despite the use of three antihyperglycemic drugs in combination. With long-standing diabetes, a significant diminution in pancreatic insulin secretory capacity dominates the clinical picture. In any patient not achieving an agreed HbA₁c target despite intensive therapy, basal insulin should be considered an essential component of the treatment strategy. After basal insulin (usually in combination with metformin and sometimes an additional agent), the 2012 position statement endorsed the addition of one to three injections of a rapid-acting insulin analog dosed before meals. As an alternative, the statement mentioned that, in selected patients, simpler (but somewhat less flexible) premixed formulations of intermediate- and short/rapid-acting insulins in fixed ratios could also be considered (44).

Over the past 3 years, however, the effectiveness of combining GLP-1 receptor agonists (both shorter-acting and newer weekly formulations) with basal insulin has been demonstrated, with most studies showing equal or slightly superior efficacy to the addition of prandial insulin, and with weight loss and less hypoglycemia (45–47). The available data now suggest that either a GLP-1 receptor agonist or prandial insulin could be used in this setting, with the former arguably safer, at least for short-term outcomes (45,48,49). Accordingly, in those patients on basal insulin with one or more oral agents whose diabetes remains uncontrolled, the addition of a GLP-1 receptor agonist or mealtime insulin could be viewed as a logical progression of the treatment regimen, the former perhaps a more attractive option in more obese individuals or in those who may not have the capacity to handle the complexities of a multidose insulin regimen. Indeed, there is increasing evidence for and interest in this approach (50). In those patients who do not respond adequately to the addition of a GLP-1 receptor agonist to basal insulin, mealtime insulin in a
The combined “basal–bolus” strategy should be used instead (51). In selected patients at this stage of disease, the addition of an SGLT2 inhibitor may further improve control and reduce the amount of insulin required (52). This is particularly an issue when large doses of insulin are required in obese, highly insulin-resistant patients. Another, older, option, the addition of a TZD (usually pioglitazone), also has an insulin-sparing effect and may
also reduce HbA\textsubscript{1c} (53,54), but at the expense of weight gain, fluid retention, and increased risk of heart failure. So, if used at this stage, low doses are advisable and only with very careful monitoring of the patient.

Concentrated insulins (e.g., U-500 Regular) also have a role in those individuals requiring very large doses of insulin per day, in order to minimize injection volume (55). However, these must be carefully prescribed, with
meticulous communication with both patient and pharmacist regarding proper dosing instructions.

Practitioners should also consider the significant expense and additional complexity and costs of multiple combinations of glucose-lowering medications. Overly burdensome regimens should be avoided. The inability to achieve glycemic targets with an increasingly con- voluted regimen should prompt a pragmatic reassessment of the HbA1c target or, in the very obese, consider- ation of nonpharmacological interven- tions, such as bariatric surgery.

Of course, nutritional counseling and diabetes self-management education are integral parts of any therapeutic program throughout the disease course. These will ensure that the patient has access to information on methods to reduce, where possible, the requirements for pharmacotherapy, as well as to safely monitor and control blood glucose levels.

Clinicians should also be wary of the patient with latent autoimmune diabe- tes of adulthood (LADA), which may be identified by measuring islet antibodies, such as those against GAD65 (56). Al- though control with oral agents is pos- sible for a variable period of time, these individuals, who are typically but not always lean, develop insulin requirements faster than those with typical type 2 di- abetes (57) and progressively manifest metabolic changes similar to those seen in type 1 diabetes. Ultimately, they are optimally treated with a regimen con- sisting of multiple daily injections of insulin, ideally using a basal–bolus ap- proach (or an insulin pump).

Figure 3 has been updated to include proposed dosing instructions for the various insulin strategies, including the addition of rapid-acting insulin analogs before meals or the use of premixed in- sulin formulations.

OTHER CONSIDERATIONS

As emphasized in the original position statement, optimal treatment of type 2 diabetes must take into account the various comorbidities that are frequently encountered in patients, particularly as they age. These include coronary artery disease, heart failure, renal and liver disease, dementia, and increasing pro- pensity to (and greater likelihood of experiencing untoward outcomes from) hypoglycemia. There are few new data to further this discussion. As mentioned, new concerns about DPP-4 inhibitors and heart failure and the is- sues concerning SGLT2 inhibitors and renal status should be taken into con- sideration (29). Finally, cost can be an important consideration in drug selection. As the prices of newer medications continue to increase, practitioners should take into account patient (and societal) resources and determine when less costly, generic products might be appropriately used.

FUTURE DIRECTIONS

More long-term data regarding the cardiovascular impact of our glucose- lowering therapies will be available over the next 1–3 years. Information from these trials will further assist us in optimizing treatment strategies. A large comparative effectiveness study in the U.S. is now assessing long-term outcomes with multiple agents after metformin monotherapy, but results are not antici- pated until at least 2020 (58).

The recommendations in this position statement will obviously need to be up- dated in future years in order to provide the best and most evidence-based rec- ommendations for patients with type 2 diabetes.

Acknowledgments. This position statement was written by joint request of the ADA and the EASD Executive Committees, which have ap- proved the final document. The process in- volved wide literature review, one face-to-face meeting of the Writing Group, and multiple revisions via e-mail communications. We grate- fully acknowledge the following experts who provided critical review of a draft of this update: James Best, Lee Kong Chian School of Medicine, Singapore; Henk Bilo, Isala Clinics, Zwolle, the Netherlands; Andrew Boulton, Manchester Uni- versity, Manchester, U.K.; Paul Callaway, Uni- versity of Kansas School of Medicine-Wichita, Wichita, KS; Bernard Charbonnel, University of Nantes, Nantes, France; Stephen Colagiuri, The University of Sydney, Sydney, Australia; Lezsek Czupryniak, Medical University of Lodz, Lodz, Poland; Margo Farber, University of Michigan Health System and College of Pharmacy, Ann Arbor, MI; Richard Grant, Kaiser Permanente Northern California, Oakland, CA; Faramarz Ismail-Beigi, Case Western Reserve University School of Medicine/Cleveland VA Medical Center, Cleveland, OH; Darren McGuire, University of Texas Southwestern Medical Center, Dallas, TX; Julio Rosenstock, Dallas Diabetes and En- docrine Center at Medical City, Dallas, TX; Geralyn Spollett, Yale University School of Med- icine, New Haven, CT; Agathocles Tsatsoulis, University of Ioannina, Ioannina, Greece; Deborah Wexler, Massachusetts General Hospital, Boston, MA; Bernard Zinman, Lunenfeld-Tanenbaum Research Institute, University of Toronto and Mount Sinai Hospital, Toronto, Canada. The final draft was also peer-reviewed and approved by the Professional Practice Committee of the ADA and the Panel on Guidelines and Statements of the EASD.

Funding. The face-to-face meeting was sup- ported by the EASD. D.R. Matthews acknowl- edges support from the National Institute for Health Research.

Duality of Interest. During the past 12 months, the following relationships with com- panies whose products or services directly relate to the subject matter in this document are declared:

R.M. Bergenstal: membership of scientific advisory board, consultation services or clinical research support with AstraZeneca, Boehringer Ingelheim, Eli Lilly, Merck & Co., Novo Nordisk, Roche, Sanofi, and Takeda (all under contracts with his employer); inherited stock in Merck & Co. (previously held by family).

J.B. Buse: research and consulting with AstraZeneca; Boehringer Ingelheim; Bristol-Myers Squibb Company; Eli Lilly and Company; Johnson & Johnson; Merck & Co., Inc.; Novo Nordisk; Sanofi; and Takeda (all under contracts with his employer).

E. Ferrannini: membership on scientific advisory boards or speaking engagements for Merck Sharp & Dohme, Boehringer Ingelheim, GlaxoSmithKline, Bristol-Myers Squibb/AstraZeneca, Eli Lilly & Co., Novartis, and Sanofi. Research grant support from Eli Lilly & Co. and Boehringer Ingelheim.

S.E. Inzucchi: membership on scientific/re- search advisory boards for Boehringer Ingelheim, AstraZeneca, Intarcia, Lexicon, Merck & Co., and Novo Nordisk. Research supplies to Yale University from Takeda. Participation in medical educa- tional projects, for which unrestricted funding from Boehringer Ingelheim, Eli Lilly, and Merck & Co. was received by Yale University.

D.R. Matthews: has received advisory board consulting fees or honoraria from Novo Nordisk, GlaxoSmithKline, Novartis, Johnson & Johnson, and Servier. He has research support from Johnson & Johnson. He has lectured for Novo Nordisk, Servier, and Novartis.

M. Nauck: research grants to his institution from Berlin-Chemie/Menarini, Eli Lilly, Merck Sharp & Dohme, Novartis, AstraZeneca, Boehringer Ingelheim, GlaxoSmithKline, Lilly Deutschland, and Novo Nordisk for participa- tion in multicenter clinical trials. He has re- ceived consulting fees and/or honoraria for membership in advisory boards and/or honoraria for speaking from Amylin, AstraZeneca, Berlin-Chemie/Menarini, Boehringer Ingelheim, Bristol-Myers Squibb, Diastis Pharmaceuticals, Eli Lilly, F. Hoffmann-La Roche, GlaxoSmithKline, Hanmi, Intarcia Therapeutics, Janssen, Merck Sharp & Dohme, Novartis, Novo Nordisk, Sanofi, Takeda, and Versartis, including reimbursement for travel expenses.

A.L. Peters: has received lecturing fees and/or fees for ad hoc consulting from AstraZeneca, Bristol-Myers Squibb, Janssen, Eli Lilly, Novo Nordisk, Sanofi, and Takeda.
A. Tsapas: has received research support (to his institute) from Novo Nordisk and Boehringer Ingelheim and receiving fees from Novartis, Eli Lilly, and Boehringer Ingelheim

R. Wender: declares he has no duality of interest

Author Contributions. All the named Writing Group authors contributed substantially to the document. All authors supplied detailed input and approved the final version. S.E. Inzucchi and D.R. Matthews directed, chaired, and coordinated the input with multiple e-mail exchanges between all participants.

References


22. Neal B, Perkovic V, de Zeeuw D, et al. Ratio- nalizing the input with multiple e-mail exchanges – fl ozin) tablets. [NDA 204042], U.S. Food and


treatments when added to metformin mono-
thrapy: a systematic review and network
meta-analysis. Diabetes Obes Metab 2014;16:
433–442
43. Bosi E, Ellis GC, Wilson CA, Fleck PR.
Alogliptin as a third oral antidiabetic drug in
patients with type 2 diabetes and inadequate
glycaemic control on metformin and pioglit-
azone: a 52-week, randomized, double-blind,
active-controlled, parallel-group study. Dia-
abetes Obes Metab 2011;13:1088–1096
Study Group. Addition of biphasic, prandial, or
basal insulin to oral therapy in type 2 diabetes. N
45. Eng C, Kramer CK, Zinman B, Retnakaran R.
Glucagon-like peptide-1 receptor agonist and
basal insulin combination treatment for the
management of type 2 diabetes: a systematic
review and meta-analysis. Lancet. 11 Septem-
ber 2014 [Epub ahead of print]
Study Group. Glucagon-like peptide 1 recep-
tor agonist or bolus insulin with optimized basal
insulin in type 2 diabetes mellitus and basal insulin treatment failure. End-
doctr Pract 2011;17:395–403
47. Buse JB, Bergenstal RM, Glass LC, et al. Use
of twice-daily exenatide in basal insulin-treated
patients with type 2 diabetes: a randomized,
controlled trial. Ann Intern Med 2011;154:
103–112
Combination therapy with GLP-1 receptor ago-
nists and basal insulin: a systematic review of
the literature. Diabetes Obes Metab 2013;15:
485–502
49. Charbonnel B, Bertolini M, Tinaones FJ,
Domingo MP, Davies M. Lixisenatide plus basal
insulin in patients with type 2 diabetes mellitus:
a meta-analysis. J Diabetes Complications. 18
July 2014 [Epub ahead of print]
50. Lane W, Weinrib S, Rappaport J, Hale C. The
effect of addition of lixisenatide to high-dose
intensive insulin therapy: a randomized pro-
spective trial. Diabetes Obes Metab 2014;16:
827–832
51. Davidson MB, Raskin P, Tanenberg RJ,
Vlajnic A, Hollander P. A stepwise approach to
insulin therapy in patients with type 2 diabetes
mellitus and basal insulin treatment failure. En-
docr Pract 2011;17:395–403
EMPA-REG MDI Trial Investigators. Improved
glucose control with weight loss, lower insulin
doses, and no increased hypoglycemia with em-
pagliflozin added to titrated multiple daily injec-
tions of insulin in obese inadequately controlled
type 2 diabetes. Diabetes Care 2014;37:1815–
1823
53. Charbonnel B, DeFranzo R, Davidson J,
et al.; PROactive investigators. Pioglitazone
use in combination with insulin in the prospec-	tive pioglitazone clinical trial in macrovascular
events study (PROactive19). J Clin Endocrinol
Metab 2010;95:2163–2171
of intensive insulin therapy alone and in combi-
nation with pioglitazone on body weight, com-
position, distribution and liver fat content in
patients with type 2 diabetes. Diabetes Obes
Metab 2011;13:505–510
55. Davidson MB, Navar MD, Echeverry D,
Duran P. U-500 regular insulin: clinical experi-
ence and pharmacokinetics in obese, severely
insulin-resistant type 2 diabetic patients. Dia-
betes Care 2010;33:281–283
56. Hawa MI, Buchan AP, Ola T, et al. LADA and
CARDS: a prospective study of clinical outcome
in established adult-onset autoimmune dia-
betes. Diabetes Care 2014;37:1643–1649
High GADA titer increases the risk of insulin re-
quirement in LADA: a 7-years of follow-up
(NIRAD Study 7). Eur J Endocrinol. 11 September
2014 [Epub ahead of print]
Study Research Group. Rationale and design of
the glycemia reduction approaches in diabetes:
a comparative effectiveness study (GRADE).
Diabetes Care 2013;36:2254–2261
59. Ismail-Beigi F, Moghissi E, Tiktin M, Hirsch
IB, Inzucchi SE, Genuth S. Individualizing glyce-
mic targets in type 2 diabetes mellitus: implica-
tions of recent clinical trials. Ann Intern Med
2011;154:554–559
60. Chiasson JL, Gomis R, Hanefeld M, Josse RG,
Karasis A, Laakso M; STOP-NIDDM Trial
Research Group. The STOP-NIDDM Trial: an in-
nernational study on the efficacy of an alpha-
glucosidase inhibitor to prevent type 2 diabetes
in a population with impaired glucose tolerance:
rationale, design, and preliminary screening
61. UK Prospective Diabetes Study (UKPDS)
Group. Effect of intensive blood-glucose control
with metformin on complications in overweight
patients with type 2 diabetes (UKPDS 34). Lan-
cet 1998;352:854–865
62. Gaziano JM, Cincotta AH, O’Connor CM,
et al. Randomized clinical trial of quick-release
bromocriptine among patients with type 2
diabetes on overall safety and cardiovascular
outcomes. Diabetes Care 2010;33:1503–
1508