

Guidelines for Glycemic Control*

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Glycemic control in diabetes patients continues to evolve as new medications are introduced and clinical trial data become available. The American Diabetes Association (ADA) guidelines for 2004, for the first time, provide targets for both preprandial and postprandial glucose levels. The ADA, however, does not provide guidelines regarding specific medication therapy. This paper provides a detailed treatment algorithm that is easy to follow for nurse practitioners as well as primary care providers. Progress in our understanding of diabetes and new therapeutic agents will dictate modifications of treatment targets and guidelines, with the goal of making euglycemia achievable for all patients with diabetes. (*Clinical Cornerstone*. 2004;6[2]:31–39) Copyright © 2004 Excerpta Medica, Inc.

INTRODUCTION

Observational as well as large, prospective, randomized studies demonstrate that achieving and maintaining glycemic control is fundamental to reducing the risk for diabetes-related microvascular complications (ie, retinopathy, nephropathy, neuropathy).^{1–3} These studies also underscore the value of testing the glycosylated hemoglobin level (A1C) to monitor glycemic control. In these large, prospective trials, patients who achieved an A1C <7% (~1% above the upper limit of normal) were unlikely to develop long-term microvascular complications. The risk for diabetes complications increased substantially with each A1C point >7%. The A1C test correlates with the patient's exposure to glycemia over the preceding 8 to 12 weeks (**Table I**).⁴ Glycemic targets recommended by the American Diabetes Association (ADA) are shown in **Table II**.⁴

BALANCING BENEFIT WITH RISKS

The potential benefit of any therapy must be balanced with its potential risks. For patients treated with

KEY POINT

Achieving and maintaining glycemic control is fundamental to reducing the risk for diabetes-related microvascular complications.

insulin, intensive glucose control is associated with significant weight gain and an increased risk of severe hypoglycemia.^{1,5} In addition, there are no clinical trial data on the risk/benefit ratio for patients with advanced complications, the elderly, or young children (<13 years of age). For this reason, less stringent treatment goals may be appropriate for patients with limited life expectancies, for the very young, or older adults, and in individuals with other comorbid conditions. For patients with a history of frequent or severe hypoglycemia, setting higher glucose targets may be appropriate.

*This issue of *Clinical Cornerstone* contains references to off-label/unapproved uses of medications. Insulin is specifically indicated only for the treatment of hyperglycemia associated with diabetes mellitus. The above article discusses issues that are considered outside the scope of the FDA-approved indication for various drugs to treat diabetes.

TABLE I. CORRELATION BETWEEN GLYCOSYLATED HEMOGLOBIN (A1C) LEVEL AND MEAN PLASMA GLUCOSE LEVELS.

A1C (%)	Mean Plasma Glucose (mg/dL)
6	135
7	170
8	205
9	240
10	275
11	310
12	345

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REDUCING RISK OF CARDIOVASCULAR DISEASE IN DIABETES PATIENTS

Cardiovascular disease is by far the most common diabetes-related complication (for a review, see the Fonseca article in this issue). Glucose control helps reduce standard cardiovascular risk factors and

TABLE II. SUMMARY OF AMERICAN DIABETES ASSOCIATION RECOMMENDATIONS FOR ADULTS WITH DIABETES.

Glycemic Control	Target
Glycosylated hemoglobin (A1C)	<7.0%*
Preprandial plasma glucose	90–130 mg/dL
Postprandial plasma glucose [†]	<180 mg/dL

Key concepts in setting glycemic goals:

- Goals should be individualized.
- Certain populations (children, pregnant women, and elderly) require special considerations.
- Less intensive glycemic goals may be indicated in patients with severe or frequent hypoglycemia.
- More stringent glycemic goals (ie, a normal A1C <6%) may further reduce complications at the cost of increased risk of hypoglycemia, particularly in those with type 1 diabetes.
- Postprandial glucose may be targeted if A1C goals are not met despite reaching preprandial glucose goals.

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*Referenced to a nondiabetic range of 4.0%–6.0% using an assay based on the Diabetes Control and Complications Trial.
[†]Postprandial glucose measurements should be made 1 to 2 hours after the beginning of the meal, generally peak levels in patients with diabetes.

reduces cardiovascular events.⁵ A major issue in diabetes therapy is determining which glucose-lowering drugs are more “friendly” with regard to reducing cardiovascular events. The UK Prospective Diabetes Study found that the available standard glucose-lowering agents—insulin, sulfonylureas, and metformin—do not *increase* the risk for cardiovascular disease.^{2,3} However, whether these agents specifically lower cardiovascular risk remains unknown. This important question is currently being addressed in several large, prospective studies.

KEY POINT

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ACHIEVING OPTIMAL GLUCOSE CONTROL

Achieving optimal glucose control in actual practice is difficult. A cornerstone of therapy that is often overlooked is aggressive lifestyle intervention. Numerous studies demonstrate that modest caloric restriction, weight loss, and an increase in physical activity are associated with improved glucose control and reduced mortality. The ADA recommends that patients with diabetes should be referred to a dietitian for medical nutrition therapy as needed to achieve treatment goals.^{4,6} Regular exercise improves blood glucose control, reduces cardiovascular risk factors, contributes to weight loss, and improves well-being.⁷ In addition to lifestyle changes, pharmacotherapy is usually required. Pharmacotherapy for type 2 diabetes includes oral medications and insulin. Although long-term prospective studies that provide algorithms for medication selection are lacking, reasonable choices can be made based on knowledge of the pathophysiology of the disease and limited clinical trial data. **Tables III, IV, V, and VI** provide detailed guidelines for medication selection based on the available data.⁸ The guidelines were designed for use by physicians and nurse practitioners in a primary

TABLE III. MEDICATION PRACTICE GUIDELINES FOR TYPE 2 DIABETES.

Glycemic targets:

- Fasting/preprandial plasma glucose: 90–130 mg/dL
 - Postprandial plasma glucose: <180 mg/dL
 - A1C <7.0%
1. Initiate, add on, or adjust oral drug therapy every 2 to 4 weeks if fasting/preprandial or postprandial targets not reached (for thiazolidinediones, allow 2 to 3 weeks to onset of action; wait 8 weeks to see maximal effect).
 2. For combination drug therapy, select only 1 drug from each class (see Table VI). Consider prescribing additional agent when dose of single agent is one half the maximum recommended dose. Select add-on agents with actions synergistic to those already prescribed.
 3. If 2-drug therapy fails to achieve targets, consider adding third oral agent or insulin therapy.
 4. Failure to achieve targets with triple oral agent therapy is an indication to initiate insulin therapy. When initiating insulin therapy, consider discontinuing insulin secretagogue.* If weight gain or edema is a problem, also discontinue or reduce the dose of thiazolidinedione. Continue metformin with insulin unless specifically contraindicated or in case of patient intolerance.
 5. For severe hyperglycemia (persistent blood glucose >300 mg/dL, significant weight loss, other severe symptoms of hyperglycemia), start insulin immediately.
 6. For hypoglycemia not caused by reduction in diet or increase in exercise, reduce the dose of or discontinue the insulin secretagogue.
 7. Insulin therapy:
 - a. Initiate with basal insulin (NPH or glargine) at bedtime and titrate upward to achieve fasting target of <100 mg/dL.†
 - b. Starting dose is 10 units at bedtime, or by weight-based calculation, 0.15–0.30 U/kg per day.
 - c. After fasting target is reached, survey daytime blood glucose levels. If daytime preprandial or postprandial blood glucose levels remain elevated, consider adding regular, lispro, or aspart before largest meal(s).
 - d. For patients who remain above target range, consider full insulin replacement with twice-daily NPH insulin or once-daily insulin glargine plus regular/lispro/aspart before largest meals.
 - e. For patients unable or unwilling to perform >2 injections per day, consider premixed insulin therapy with NPH/rapid-acting insulin analogs, Novolog mix 70/30, or Humalog mix 75/25, given in the morning before breakfast and before dinner.
 - f. Titrate insulin(s) individually to reach target blood glucose levels.
 - g. For patients using insulin before meals, educate on consistent carbohydrate diet or carbohydrate counting with premeal insulin adjustment.
 - h. For patients participating in regular exercise, educate on appropriate insulin dose reductions before exercise.
 - i. Insulin therapy may be reconsidered, if appropriate, once glucose toxicity is resolved—it may be possible to convert back to combination oral therapy.
 8. Notify physician at time of initiation of any new oral medication or insulin.
 9. Instruct patient on sick-day guidelines for medications.
 - a. If on oral agents, and oral intake is markedly reduced, hold insulin secretagogue.
 - b. Continue metformin or thiazolidinedione unless severely ill (eg, marked nausea, vomiting, shortness of breath).
 - c. Insulin: Continue at usual doses, unless marked decrease in oral intake is known to be associated with hypoglycemia; monitor blood glucose every 4 hours. Take supplemental doses of insulin if blood glucose is elevated.

Adapted with permission.⁸

NPH = neutral protamine Hagedorn.

*The patient's insulin requirement may be significantly less if sulfonylurea therapy is continued (eg, 45 vs 70 units insulin). Basal insulin may be combined with preprandial meglitinide.

†Bedtime basal insulin titration schedule, adjusted weekly:

Mean of Fasting Blood Glucose Values from Preceding 2 Days (mg/dL)	Increase in Bedtime Insulin Dose
≥ 180	8
140–180	6
120–139	4
100–119	2

Exceptions to this algorithm: (1) No increase in dose if blood glucose <72 mg/dL at any time in the preceding week; (2) small insulin dose decreases (2–4 units/d) may be initiated if severe hypoglycemia (requiring assistance for treatment) or blood glucose <56 mg/dL occurred in the preceding week.

care practice. In addition, several reviews on the outpatient use of insulin therapy have been recently published.⁹⁻¹¹

CONCLUSION

Practice guidelines and targets for glycemic control have undergone dramatic changes over the past few years. Guidelines now reflect a new emphasis on tight glycemic control. Better understanding of the importance of near-normal glucose control and the introduction of new medications have spearheaded these changes. Achieving and maintaining these goals are

considerable challenges for the patient and the health-care team. It is hoped that future progress in our understanding of the pathophysiology of diabetes and development of new therapeutic agents will make the goal of euglycemia achievable for all patients with diabetes.

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1. The Diabetes Control and Complications Trial Research Group (DCCT). The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med.* 1993; 329:977-986.

TABLE IV. GUIDELINES FOR SELECTING ORAL MEDICATIONS FOR PATIENTS WITH DIABETES.

Metformin

- Consider as first choice for patients who are obese or who have dyslipidemia with normal renal/liver function.
- Contraindications:
 - Creatinine ≥ 1.4 mg/dL (women) or ≥ 1.5 mg/dL (men)
 - Age ≥ 80 y
 - CHF requiring drug treatment, particularly if history of decompensation
 - Severe lung disease predisposing to hypoxia
 - Alcohol abuse
- Discontinue drug before iodinated contrast tests (CT, angiogram), surgery, or in case of severe illness requiring hospitalization.
- Side effects:
 - GI upset
 - Diarrhea and nausea (if mild, often resolves in 2-3 weeks with continuation of therapy)
 - If vomiting or abdominal pain occur, discontinue therapy
 - Lactic acidosis

Insulin Secretagogues

- Consider as first choice for nonobese or mildly obese patients.
- Low doses are often effective, even in obese subjects—may not need to titrate to maximum dose.
- Sulfonylureas are contraindicated in severe liver or renal disease.
- Avoid glimepiride and glyburide in patients prone to hypoglycemia (especially the elderly).
- Minimal adverse reactions include GI upset, rashes.

Thiazolidinediones

- Use to treat hyperglycemia with evidence of insulin resistance (acanthosis nigricans, skin tags).
- Baseline ALT must be checked—use of other agents preferable if *any* elevation in ALT. Absolutely contraindicated if ALT ≥ 2.5 times the upper limit of normal.
- ALT must be monitored every 2 months of therapy for first year. Discontinue if ALT exceeds 3 times upper limit of normal.
- Contraindications:
 - New York Heart Association Class III and Class IV CHF
 - Edema
- Use with caution in combination with insulin (may cause severe weight gain).

Alpha-glucosidase Inhibitors

- Consider for mild hyperglycemia and predominantly postprandial hyperglycemia.
- May be useful adjunct for elderly patients with type 2 diabetes who have symptomatic hypoglycemia, or for patients in whom other oral agents are contraindicated.
- If hypoglycemia occurs when used with hypoglycemic agents, treat with simple carbohydrate.
- Adverse reactions include flatulence, bloating.
- Titrate dose slowly to minimize side effects.

CHF = congestive heart failure; CT = computed tomography; GI = gastrointestinal; ALT = alanine aminotransferase.

TABLE V. GUIDELINES FOR INSULIN ADMINISTRATION IN OUTPATIENTS.

Human insulin preparations may provide basal or prandial and/or supplemental insulin action. Basal insulin is used to control fasting and between-meal glucose levels. Prandial insulin controls postprandial glucose excursions. Supplemental insulin doses are used for the correction of hyperglycemia.

Basal insulin needs are met by neutral protamine Hagedorn (NPH), Lente, Ultralente, and/or glargine preparations. To provide a continuous basal insulin effect over a 24-hour period, NPH and Lente insulin are generally given twice daily, before breakfast and at dinner or bedtime. Ultralente and glargine are administered once daily, generally at bedtime.

Prandial and supplemental/correction insulins include short-acting regular insulin and rapid-acting aspart or lispro insulin preparations. Regular insulin is administered 30 to 45 minutes before meals and aspart or lispro 0 to 15 minutes before meals, to allow time to onset of action of each to match the postprandial rise in blood glucose level.

Guidelines for starting insulin doses

It is generally safe in the outpatient setting to begin basal insulin at a dosage of 10 units once daily, subcutaneously, either at bedtime or before breakfast. In type 2 diabetes, the usual total daily insulin requirement is 0.4 to 1.0 units/kg. Half (50%) of this amount is generally given as basal insulin. To ensure minimum risk of hypoglycemia, when starting insulin in the outpatient setting, begin with a daily dose of 0.2 to 0.5 units/kg. The remainder is divided into prandial doses. Individual doses vary widely. Frequent adjustments based on resultant blood glucose finger stick testing results and knowledge of the pharmacokinetics of each insulin preparation should be made until target blood glucose levels are reached.

Insulin Preparation	Onset	Peak	Duration
Prandial/Supplemental/Correction			
Rapid-acting (lispro, aspart)	5–15 min	1–2 h	2–4 h
Short-acting (regular)	30–45 min	2–4 h	6–10 h
Basal			
Intermediate-acting (Lente, NPH)	1–2 h	6–8 h	10–12 h
Long-acting (glargine)	1–2 h	Flat	~24 h
Long-acting (Ultralente)	2–4 h	Variable	16–24 h

Time courses of action may vary. Time periods shown are general guidelines only.

TABLE VI. ORAL DIABETES MEDICATIONS.*

Drug Class/Drug	Brand Name	Available Doses	Dosage Regimen
Biguanides			
Metformin*	Glucophage® (Merck Santé, SAS), Glucophage XR	500, 850, 1000 mg	Start at 500 mg bid, titrate to 1000 mg bid
Thiazolidinediones			
Pioglitazone	Actos® (Takeda)	15, 30, 45 mg	Once daily
Rosiglitazone	Avandia® (GlaxoSmithKline)	2, 4, 8 mg	Once daily, or 2–4 mg bid
Insulin Secretagogues			
Glimepiride	Amaryl® (Aventis)	1, 2, 4 mg	Once daily
Glipizide*	Glucotrol (Pfizer), Glucotrol XL	2.5, 5, 10 mg	Once daily for XL, otherwise twice daily
Glyburide*	Diabeta® (Aventis), Micronase® (Pfizer)	1.25, 2.5, 5, 10 mg	Once daily, start at low dose if at risk for hypoglycemia
Repaglinide	Prandin® (Novo Nordisk)	0.5, 1, 2 mg	Start at 0.5 mg, 15–30 min before meals
Nateglinide	Starlix® (Novartis)	60, 120 mg	Start at 120 mg, 1–30 min before meals
Alpha-glucosidase Inhibitors			
Acarbose	Precose® (Bayer)	25, 50, 100 mg	Start at 25 mg at start of meal
Miglitol	Glyset® (Pfizer)	25, 50, 100 mg	Start at 25 mg at start of meal

*Available generically.

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Dialogue Box

EDITORIAL BOARD

What is the current thinking on the importance of the glycemic index in food selection?

CLEMENT

It's still an area of controversy. A few studies have shown that the postprandial glucose excursion is reduced when a person eats a food with a low glycemic index. The problem with interpreting these studies lies in the way the glycemic index is determined; it has its basis on glucose measurements after the isolated intake of a single food (eg, a piece of bread, a portion of beans or brown rice), rather than within the context of a regular meal. As a result, it is unknown whether any benefit of a food with a low glycemic index is lost when eaten in a mixed meal. Nevertheless, the ADA's dietary recommendations that you limit carbohydrates to 50% of caloric intake and that you eat a diet rich in fiber and grain should result in the glycemic index taking care of itself.

EDITORIAL BOARD

Let's walk you through a common scenario seen in practice and see how you would manage it. A 45-year-old male is seen for a 3-week history of polyuria, polydipsia, and polyphagia. He is found to have a random glucose level of 310 mg/dL, and you make the diagnosis of diabetes. What factors do you consider when deciding whether to treat the patient with a trial of diet and exercise alone or to start the patient on both an oral agent and lifestyle measures?

CLEMENT

Lifestyle measures are paramount in such a patient. I spend 90% of the first visit explaining and emphasizing the importance of lifestyle interventions to patients with diabetes. In a patient like the one you've just described, I would likely initiate a low dose of metformin. I would do this primarily because of the findings of the Diabetes Prevention Program. This

study found that metformin, independent of lifestyle, not only reduced progression of disease but also was safe and well tolerated. As a result, I typically prescribe low-dose metformin regardless of how well the patient might do with diet and exercise alone.

EDITORIAL BOARD

How do you decide whether glucose toxicity is present and whether the patient requires insulin therapy to achieve normoglycemia and restore β -cell function?

CLEMENT

I make that determination based on what's going on with the patient as well as the phenotype of the patient. If the patient appears insulin resistant and has other features of metabolic syndrome (ie, hypertension, truncal obesity, hypertriglyceridemia, low level of high-density lipoprotein cholesterol), and the glucose level is 350 mg/dL or below, I would aggressively treat that person with diet and exercise and use combination drug therapy. My preferred combination is metformin plus a thiazolidinedione (TZD) or possibly metformin plus an oral sulfonylurea because, in the interest of patient convenience and compliance, both of these combinations are available in a single pill. On the other hand, in patients who are thin and have no features suggestive of metabolic syndrome, and particularly if their glucose levels are above 350 mg/dL and they have been losing weight, I usually will start insulin right away, because those features are indicative of insulin deficiency. I really won't know whether this means that they're going to be on insulin for life until I get their glucose levels down and see their response to treatment.

EDITORIAL BOARD

How long a trial of oral therapy would you give an overweight patient with type 2 diabetes before you would suspect glucose toxicity and consider insulin therapy?

Dialogue Box

CLEMENT

If I were to place that patient on metformin and glyburide, and if the fasting glucose were still above 200 mg/dL after 10 days or so, I would be suspicious enough of glucose toxicity to initiate insulin therapy.

EDITORIAL BOARD

Would you start by adding basal insulin therapy to the oral regimen?

CLEMENT

That is what I typically do. I was very impressed by the Treat-to-Target study, which employed a very aggressive basal insulin protocol that titrated the bedtime insulin dose (using either insulin glargine or human neutral protamine Hagedorn insulin) based on the fasting glucose level measurement from the previous morning. After instructing patients on how to properly administer insulin, I have them titrate their insulin doses using the same protocol provided in my article.

EDITORIAL BOARD

How long do patients with glucose toxicity need to be treated with insulin before they regain β -cell function and become responsive to oral agents?

CLEMENT

Usually, it takes about a week. Once you get the fasting glucose level down to <100 mg/dL, the postprandial glucose usually falls into line very rapidly. If it doesn't, then you're dealing with more than just glucose toxicity and something else is responsible for the impairment in β -cell function.

EDITORIAL BOARD

When you initiate basal insulin, do you just add it to whatever oral regimen the patients are already taking?

CLEMENT

I usually have them continue the same oral regimen they're already taking, unless those regimens include the use of a sulfonylurea. There are quite a few long-term observational studies that have shown that continuing to use metformin while initiating insulin therapy reduces the insulin dose subsequently required, and there's actually some data that it may improve mortality as well. I generally also have patients continue to use TZDs unless excessive weight gain has been a problem.

EDITORIAL BOARD

Why do you stop the sulfonylurea?

CLEMENT

Although the Treat-to-Target study simply continued patients on their oral regimens regardless of the agents they were taking, my own personal practice is to stop sulfonylurea agents when initiating insulin therapy. The reason for this is that I use hypoglycemia as one of my end points. If patients were to continue to use a sulfonylurea in conjunction with bedtime insulin and subsequently developed hypoglycemia, I wouldn't be certain which of the agents was responsible. This is not an issue with metformin or TZDs because they do not cause hypoglycemia.

EDITORIAL BOARD

When starting a patient on a TZD, what dose do you begin with and at what point would you increase the dose?

CLEMENT

My practice has been to begin with a midrange dose. For pioglitazone, I start at 30 mg/d. For rosiglitazone, I begin at 4 mg/d. Because these agents exert more of a long-term effect, I tell the patient up front that we don't expect to see any marked changes in their blood glucose for at least 3 to 4 weeks. The advantage of the TZDs is that, once they start working, they tend to provide more sustained metabolic

Dialogue Box

control than do the other drugs. Before increasing the dose, I wait a full 8 weeks because it takes that long to see the maximal glyceemic effect.

EDITORIAL BOARD

Can these agents be safely used in patients with nonalcoholic steatohepatitis (NASH)?

CLEMENT

In most patients with NASH, TZDs can be safely prescribed. I use the alanine aminotransferase guidelines in my article as a guide. That is, as long as the transaminase levels are no more than 3 times the upper limit of normal, these agents can be safely started and/or continued. In addition, these patients also need to be encouraged to lose weight, exercise, and reduce their other risk factors.

EDITORIAL BOARD

What about chronic hepatitis B or C?

CLEMENT

In patients with chronic hepatitis B or C infections, I generally refrain from using TZDs. The Rezulin nightmare is still very clear in people's minds. Although the 2 TZDs currently available have been fairly risk-free, I still think people need to be fairly cautious regarding patient selection.

EDITORIAL BOARD

How do you advise patients receiving insulin therapy about the precautions they should take prior to exercise?

CLEMENT

There are some very nice studies that show if a person is on full insulin replacement (taking basal

insulin and preprandial insulin), they can very safely exercise by timing their exercise activity approximately 1½ hours after eating. This is a long enough delay that they shouldn't get cramps but is soon enough after eating that they will still be absorbing nutrients, which will guard against the development of hypoglycemia. In addition, depending on how vigorously they plan to exercise, I may also advise them to reduce their premeal insulin dose by 20% to 30%. A safe guideline for exercise is to make sure that the glucose level is between 180 and 200 mg/dL so there will be some leeway for the glucose level to drop further.

EDITORIAL BOARD

Can you safely use a sulfonylurea in a patient with a history of sulfa allergy?

CLEMENT

There's absolutely no issue. The chance of a cross-over sulfa allergy from sulfa drugs and sulfonylurea is almost zero.

EDITORIAL BOARD

How many days before a contrast radiograph or surgery must metformin therapy be stopped?

CLEMENT

Current guidelines for simple radiographic and surgical procedures call for stopping metformin therapy the night before the procedure. In other words, tell patients not to take their morning dose. Therapy can be restarted once renal function is evaluated as normal after the procedure.