# Principles of Care in the Diabetic Surgical Patient

1

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**Abstract**

The prevalence of diabetes in the USA continues to grow at an alarming rate. While the risk factors for diabetes complications are well defined, many patients are not achieving recognized treatment goals and are at risk of developing complications, including peripheral vascular disease and podiatric problems. There are two major types of diabetes—Type 1 and Type 2. Type 1 diabetes develops into a from of insulin production while Type 2 diabetes develops because of insulin resistance with an inadequate supply of insulin to meet the increased need. When patients with diabetes are admitted to the hospital, they will almost always require insulin therapy. Optimal insulin coverage includes basal (background) insulin in conjunction with insulin. The bolus insulin dose is composed of a prandial (meal) component and a correction dose as needed. For patients eating normally the total daily dose of prandial insulin is approximately equal to the total basal dose. Based on a patient's total daily insulin requirement, one can calculate a correction factor or the amount of blood glucose lowering expected from 1 unit of insulin. Patients with Type 1 diabetes, because of their lack of insulin production, can never have all of their insulin held because of the risk of developing DKA. Adjustments in both the basal and bolus doses are required preoperatively. Patients in the ICU are best managed with an intravenous insulin infusion with dosing based on a validated protocol. Early discharge planning can help avoid delays in discharge due to diabetes-related issues.

**Keywords**

Type 1 diabetes • Type 2 diabetes • Inpatient • Insulin • Insulin infusion • Ketoacidosis • Basal • Bolus • Prandial • Correction factor • Correction dose • Glargine • Detemir

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## Introduction

We are in the midst of a diabetic epidemic. The prevalence of diabetes in the USA as well as worldwide continues to grow at an alarming rate. This growth is due mostly to an increase in the number of cases of Type 2 diabetes related to obesity. According to the CDC in 2010, the most recent year for which we have data, it was estimated that 25.8 million people or about 8.3% of people in the USA had diabetes. The incidence of new cases of diabetes is about 1.9 million cases each year meaning that a more realistic estimate puts the diabetes burden in the USA in 2012 to 28 million people [1]. The complications of diabetes are well known and studies have clearly shown that the risk of complications is dependent on identified risk factors. The risk of retinopathy, nephropathy, and neuropathy, as well as macrovascular complications is influenced by the level of glycemic control as well as other risk factors, such as blood pressure, lipid levels, and smoking [2–4]. Unfortunately, the level of control of these risk factors in the USA is far from optimal [5]. Thus, many patients diagnosed with diabetes and under treatment are at high risk for complications, including peripheral vascular disease due to inadequate glycemic control.

## Pathophysiology of Diabetes

Glucose, the predominant source of energy for cell metabolism, is actively transported into cells. This process requires insulin, a hormone produced in beta cells of the pancreas, to bind to an insulin receptor on the cell surface. This binding then leads to phosphorylation of intracellular proteins causing the movement of glucose transport facilitators to move to the cell surface leading to glucose diffusion into the cell [6]. Diabetes mellitus is a condition caused by the inability to efficiently move glucose from the blood into cells. There are two major forms of diabetes—Type 1 diabetes mellitus accounting for approximately 5% of the total cases of diabetes and Type 2 diabetes mellitus accounting for approximately 95% of total cases. In Type 1 DM, there is an absolute deficiency of insulin. Type 1 diabetes was previously referred to as juvenile diabetes because the disease is more likely to occur during childhood with the peak incidence between 8 and 14 years old [7]. In addition to this peak in incidence during the second decade of life, it is now recognized that many cases of Type 1 diabetes will occur in adults with an increased risk during the 6th and 7th decades of life. The incidence of Type 1 diabetes in these later decades actually exceeds the risk in children [8, 9]. In Type 2 diabetes, there is resistance to the action of insulin coupled with a relative deficiency of insulin that is inadequate to meet the increased need [10]. Type 2 diabetes was previously referred to as adult onset diabetes since it is more likely to occur later in life. Since insulin resistance is worsened by obesity, there has been a significant increase in the incidence of Type 2 diabetes. This increase has been seen in all ages of the population, including teenagers. Because Type 1 diabetes does occur in older individuals and because Type 2 is increasing in younger patients, the age of the patient is not a reliable way to identify the type of diabetes present.

Type 1 diabetes is caused by an autoimmune process that selectively destroys the beta cells leading to a reduction in the amount of insulin available. This process can begin years before any clinical manifestations of the disease [10]. As the process continues, the number of beta cells and the amount of insulin produced eventually reaches a level that is inadequate to allow sufficient intracellular transport of glucose. When this level is reached, glucose levels climb significantly. Insulin, however, is not only necessary for the utilization of glucose but is also essential in the regulation of lipolysis. In the absence of insulin, fat breakdown is accelerated with an increased production of ketone bodies. Thus, the production of ketones in a patient with Type 1 diabetes is a sign of insulin deficiency. Untreated, this process accelerates with an increase in the level of ketones. Ketones are acidic and will lead to ketoacidosis if left untreated. Therefore, it is important to remember that a patient with Type 1 diabetes requires some background level of insulin at all times to prevent the production of ketones. The situation is true even in the patient who is not eating. Failure

**Table 1.1** Currently available noninsulin diabetes medications

| Generic name (product name) | Action |
|---|---|
| *Sulfonylureas* | |
| Glimeperide (Amaryl)<br>Glipizide (Glucotrol)<br>Glyburide (Diabeta) (Micronase) | Stimulate beta call insulin production |
| *Non-SFU secretagogues* | |
| Repaglinide (Prandin)<br>Nateglinide (Starlix) | Stimulate beta call insulin production |
| *Biguanides* | |
| Metformin (Glucophage) (Fortamet) | Decreases hepatic glucose production and improves insulin sensitivity |
| *Alpha-glucosidase inhibitors* | |
| Miglitol (Glyset)<br>Acarbose (Precose) | Delays absorption of carbohydrates from the intestines |
| *Thiazolidinediones* | |
| Pioglitazone (Actos)<br>Rosiglitazone (Avandia) | Improves insulin sensitivity and decreases hepatic glucose production |
| *GLP-1 agonists* | |
| Exenatide (Byetta) (Bydureon)<br>Liraglutide (Victoza) | Increases level of incretin hormone resulting in enhanced insulin sensitivity |
| *DPP-4 inhibitors* | |
| Linagliptin (Tradjenta)<br>Saxagliptin (Onglyza)<br>Sitagliptin (Januvia) | Increases level of incretin hormone resulting in enhanced insulin sensitivity |
| *Bile acid sequestrants* | |
| Colesevelam (Welchol) | Bile acid sequestrant |
| *Dopamine agonists* | |
| Bromocriptine (Cycloset) | Unknown |
| *Fixed combinations* | |
| Glipizide and Metformin (Metaglip)<br>Glyburide and Metformin (Glucovance)<br>Linagliptin and Metformin (Jentadueto)<br>Pioglitazone and Glimeperide (Duetact)<br>Pioglitazone and Metformin (Actoplus met)<br>Repaglinide and Metformin (Prandimet)<br>Rosiglitzone and Glimeperide (Avandaryl)<br>Rosiglitzone and Metformin (Avandamet)<br>Saxagliptin and Metformin (Kombiglyze XR)<br>Sitagliptin and Metformin (Janumet)<br>Sitagliptin and Simvastatin (Juvisync) | See actions of individual components |

to provide background insulin can lead to diabetic ketoacidosis (DKA) quite quickly [11].

Patients with Type 2 diabetes are resistant to the action of insulin. This insulin resistance is present for years prior to the development of Type 2 diabetes. In response to this level of insulin resistance, the patient's beta cells increase the amount of insulin that is produced maintaining glucose in a normal range. Over the course of time, these beta cells produce less insulin with a resulting increase in glucose levels. Unlike patients with Type 1 diabetes, patients with Type 2 diabetes still produce some insulin. Even though this amount of insulin may not be adequate to maintain blood glucose levels in the normal range, the amount of insulin produced is almost always adequate to prevent the development of significant ketosis. Therefore, the development of DKA in a patient with Type 2 diabetes is rare [12].

A number of different medications can be used in the treatment of Type 2 diabetes. These medications may improve insulin resistance, increase the amount of available insulin through increasing endogenous production or provide additional exogenous insulin. Frequently, multiple different therapies are combined to take advantage of different modes of action. A list of available medications is provided in Table 1.1.

Diabetes, especially when inadequately controlled, can lead to a number of complications. These include retinopathy, nephropathy, neuropathy, and macrovascular disease. In fact, in the USA, diabetes is the leading cause of blindness in adults under the age of 65 and the leading cause of preventable blindness in adults age 20–74. It is also the leading cause of renal failure and accounts for over 60% of the nontraumatic lower extremity amputations that are performed each year [1]. The goal in treating a patient with diabetes is to control the blood glucose level as well as other risk factors in order to prevent or minimize the risk of developing complications. Despite the recognition of the need for good glycemic control and the availability of numerous medications to improve blood glucose control, many patients are still inadequately treated. Studies have shown that as many 20% of patients are under poor control and 63% are under suboptimal control [5]. Thus, many patients are at an increased risk of complications because of an inadequate treatment of the blood glucose levels.

## Peripheral Vascular Disease in Patients with Diabetes

Peripheral vascular disease is a common cause of hospitalization among patients with diabetes. In 2003, there were 873,000 patient discharges with a lower extremity condition (peripheral vascular disease, ulcer/infection, or neuropathy) listed as either the primary or secondary diagnosis among patients with diabetes. This number more than doubled over the previous 20 years [13]. In general, the annual number of diabetes-related hospital discharges with lower extremity nontraumatic amputation as a reported procedure increased from about 33,000 in 1980 to 84,000 in 1997. The number of lower extremity amputation discharges increased significantly in the early 1990s and then leveled off and has been slowly decreasing more recently. This decrease may reflect an improvement in the chronic care of patients with diabetes, a heightened awareness of the seriousness of lower extremity problems in this population as well as improved surgical evaluation and revascularization. In 2006, there were about 66,000 diabetes-related hospital discharges with lower extremity amputation [14].

## Considerations for the Inpatient Management of Diabetes

There are a number of issues to consider in treating the patient with diabetes after they are admitted to the hospital. These issues include the differences in pathophysiology between Type 1 and Type 2 diabetes, the wide variety of treatment regimens employed in outpatient treatment as well as the great variability in degree of control among patients with diabetes. While no single set of rules can apply to all patients, utilizing certain fundamental principles can help one develop a reasonable diabetes management plan for the vast majority of patients.

### Patients with Type 2 Diabetes

For patients with Type 2 diabetes the major goal of therapy is to achieve good glycemic control. As an outpatient, people with Type 2 diabetes may be on lifestyle therapy only, oral antidiabetes medications, injectable medication or insulin either alone or in combination with any of the above. The first decision that must be made is whether to continue antidiabetes medications during hospitalization in those patients who are on those therapies as an outpatient. For the vast majority of patients, the answer is no and they should be on insulin therapy for the duration of their hospitalization. Most patients who are hospitalized should be switched to insulin because of the many changes that occur in the need for therapy during hospitalization and the greater degree of adjustments that can be made with insulin [15]. There may still be a role for noninsulin therapy in the small number of patients who are admitted for brief hospital stays who will not be in the hospital long enough to have their insulin regimen adjusted and they do not have a contraindication to continuing their present therapy and will be

eating on a regular schedule [16]. If an inpatient is continued on their outpatient regimen, then one must be ready to switch to insulin when it becomes apparent that the patient will not be discharged within 24–48 h. The vast majority of patients with Type 2 diabetes will need insulin therapy when admitted.

### Patients with Type 1 Diabetes

For patients with Type 1 diabetes, one must consider the goal of good glycemic control similar to the patient with Type 2 diabetes. In addition, one must keep in mind that patients with Type 1 diabetes produce no insulin. Because of this endogenous insulin deficiency if insulin is withheld for more than a few hours, patients will begin to produce ketones and then develop DKA. Therefore, all patients with Type 1 diabetes admitted to the hospital must continue to have ongoing background insulin. Because they are not able to produce any insulin, they will need additional insulin for any food they eat. For these reasons, under no circumstance a patient with Type 1 diabetes can be treated with sliding scale insulin only.

### Hemoglobin A1c Testing

All patients with diabetes should have an hemoglobin A1c (HgbA1c)performed on admission. This test is a measure of the average glycemic control over the prior 2–3 months. Knowing the HgbA1c provides at least three benefits. The first, for those patients who are on insulin therapy, is the ability to know whether the patient's outpatient insulin regimen has been adequate. If the HgbA1c result reflects poor control, then one knows that the patient's outpatient insulin regimen was not adequate and that there is a great likelihood that the regimen will not effectively control the patient during their hospitalization. As such, one should be prepared for the need to adjust the insulin regimen. The second benefit that can be achieved by knowing the HgbA1c is to better anticipate discharge planning needs. For the patient with Type 2 diabetes on oral therapy only who has a very high HgbA1c, it is clear that this therapy was not adequate for the patient and that most likely they will need to be discharged on insulin. Knowing this need early in the hospitalization will provide time to arrange for diabetes teaching in insulin use. In addition, patients already on insulin who need adjustment and intensification in their insulin regimen may also benefit from teaching prior to discharge. Finally, for those patients who are under poor control as an outpatient, consultation with a specialist might be beneficial.

## Insulin Management

### Insulin Management on a General Floor

There is substantial observational data connecting hyperglycemia during hospitalization to poor outcomes [17, 18]. Yet, there are no prospective randomized controlled trials establishing specific targets for glycemic control in noncritically ill patients. Guidelines based on expert judgment and clinical experience have been published jointly by the American Association of Clinical Endocrinologists and the American Diabetes Association. These guidelines call for premeal blood glucose levels to be less than 140 mg/dL with random blood glucose levels less than 180 mg/dL and to reassess the insulin regimen if the blood glucose level falls below 100 mg/dL. Patients who demonstrate the ability to maintain tight glycemic control as an outpatient may have a tighter range for glucose control compared to those patients who have significant comorbidities who may need less stringent glucose targets [19].

The recommended subcutaneous insulin regimen for noncritically ill patients involves the use of basal and bolus insulin. See Table 1.2 for a list of available insulins. The basal insulin is a long-acting insulin that provides background insulin to maintain good glycemic control overnight and between meals. The bolus insulin is a short-acting insulin that provides insulin coverage for food consumed (prandial dose) as well as insulin to correct for high blood glucose readings (correction dose). This approach to insulin dosing

**Table 1.2** Available insulins

| | Generic name | Product name |
|---|---|---|
| Basal insulin | Detemir<br>Glargine | Levemir<br>Lantus |
| Intermediate insulin | Insulin NPH | Humulin N<br>Novolin N |
| Short-acting insulin | Insulin regular | Humulin R<br>Novolin R |
| Rapid-acting insulin | Insulin Aspart<br>Insulin Glulisine<br>Insulin Lispro | Novolog<br>Apidra<br>Humalog |
| Premix insulins | Insulin NPH/regular<br>Insulin Aspart Protamine/Insulin Aspart<br>Insulin Lispro Protamine/Insulin Lispro | Humulin 50/50<br>Humulin 70/30<br>Novolin 70/30<br>Novolog mix 70/30<br>Humalog mix 50/50<br>Humalog mix 75/25 |

Premix insulin is a combination of intermediate-acting insulin and short- or rapid-acting insulin. The numbers in the product name reflect the percentage of the intermediate- and short- or rapid-acting insulin, respectively—i.e., Humulin 70/30 is 70% intermediate-acting NPH insulin and 30% short-acting regular insulin.

was shown to be superior to the use of only sliding scale insulin in the Rabbit 2 Trial [20]. There are numerous recommendations for approaching insulin dosing. The most important fact to recognize is that regardless of what starting dose of insulin is used adjustment in the dose will almost always be needed to achieve an adequate level of control. Even patients who are well controlled as an outpatient are likely to require adjustment to their insulin dosing when hospitalized.

For patients not on insulin as an outpatient, the initial dose of basal insulin can be calculated using 0.15–0.2 units/kg of body weight. Thus, the initial dose for a 100 kg patient who needs to start on insulin would be 15–20 units of basal insulin daily. In the Rabbit 2 Trial, an initial basal dose of 0.2 units/kg of body weight was used [20].

For patients who are on basal insulin as an outpatient, the initial basal dose of insulin can simply be a continuation of the outpatient dose. For those patients not on basal insulin but are on the intermediate-acting NPH insulin administered once each day the initial basal dose can also be a continuation of the outpatient dose. If the patient is on twice daily NPH and switching to detemir, then the basal dose can be equal to the outpatient dose. But, if switching from twice daily NPH to glargine, the dose of glargine should be calculated as 80% of the total daily NPH dosage [21, 22].

The total daily prandial insulin requirement, which is the amount of bolus insulin administered prior to meals when the blood sugar is under control, should be approximately equal to the total basal dose. Thus, half of the daily dosage of insulin will be administered as basal insulin and half will be administered as bolus insulin. In the Rabbit 2 Trial, the initial total prandial dose was equal to the initial basal dose [20]. The prandial dose was then divided into three equal doses for each meal. A common misconception is that the amount of bolus insulin required each day is adequate even when it comprises only a small proportion of the total daily insulin dosage. This situation is commonly seen when bolus insulin is ordered by sliding scale with the dose starting at 2 units for a blood glucose level of 150 mg/dL. Frequently, the result is significant hyperglycemia during the day. Fasting blood glucose levels may not be very elevated but a consistent climbing of blood glucose as the day progresses is seen because of inadequate prandial coverage. Providing adequate prandial insulin coverage

will allow good glycemic control with a lower risk for hyperglycemia [20]. Matching up the amount of prandial insulin needed with an appropriate dose is less likely to induce hypoglycemia than providing inadequate prandial insulin followed by an increased amount of basal insulin. With too little prandial insulin patients are far more likely to have elevated blood glucose levels, especially later in the day, followed by an excess of basal insulin putting the patient at risk for hypoglycemia especially while fasting such as during the night. Providing adequate prandial insulin will help avoid these swings in blood glucose. For patients who are not eating the prandial dose of insulin is simply zero.

The correction dose of bolus insulin is used to correct elevated blood glucose levels. The amount of insulin needed is added to the prandial dose of insulin to arrive at the total amount of bolus insulin administered prior to each meal. Clearly, patients who require smaller amounts of insulin each day are more sensitive to the action of insulin and will have a greater correction per unit of insulin compared to a patient who requires a greater amount of insulin each day demonstrating a greater degree of insulin resistance. Again, there are any number of approaches to estimate the correction dose. One such approach is the "rule of 1800" [23]. Originally developed by Paul Davidson in Atlanta as the rule of 1500 when using regular insulin, the rule was modified to take into account the fact that rapid-acting analog insulin will drop blood glucose faster and further. The rule relates the total daily dose of insulin to the amount of blood glucose lowering that will occur with 1 unit of insulin. The rule of 1800 states that taking 1800 and dividing by the total daily dose of insulin will equal the correction factor (the amount of blood glucose lowering that will occur with 1 unit of insulin):

$$\frac{1800}{\text{TDD}} = \text{CF}.$$

For example, a patient who is on a total daily dose of 36 units each day will likely lower their blood glucose by 50 mg/dL for each unit of correction insulin they receive (1800/36). A patient on 72 units total each day will lower their blood glucose only 25 mg/dL for each unit of insulin they receive and would need 2 units to lower their blood glucose 50 mg/dL. For examples of insulin dosing, see Figs. 1.1 and 1.2.

After the patient is on an appropriate insulin regimen, one must reassess whether the dosage is appropriate. The simplest way to assess the adequacy of the basal dose is to see what happens to the blood glucose over time when the patient is not eating. This can be accomplished by observing any change in blood glucose overnight. If the dose of basal insulin is adequate, then the blood glucose should remain relatively flat overnight. If the blood glucose drops significantly, then the dose of basal insulin is too high. Likewise, if the blood glucose climbs overnight, then the dose of basal insulin needs to be increased.

The simplest way to assess the dose of bolus insulin is to assess the change in blood glucose before and then after the dose. This assessment can be done by looking at the change in blood glucose from prebreakfast to the prelaunch reading, from the prelaunch to the presupper reading and then from presupper to the nighttime blood glucose reading. If the bolus dose of insulin is adequate, then the prandial dose should be enough to cover the food that is eaten. Thus, if the blood glucose prior to the meal is good and no correction dose is given, then the next reading should also be in the desired range. If the blood glucose climbs, then the prandial dose is inadequate. If the premeal blood glucose level is elevated, then the bolus dose (composed of the prandial insulin and the correction dose) should cover the food eaten and correct the blood glucose so that the next reading should be within the desired range. If the next reading is still above goal, then the bolus dose is not adequate and the prandial and correction needs to be increased. An inadequate correction dose should be fixed by increasing the bolus insulin and not by increasing the basal dose.

## Insulin Pumps

Some patients admitted to the hospital may be treating their diabetes as an outpatient utilizing

| | Before breakfast, lunch and supper | | Before bedtime | |
|---|---|---|---|---|
| Blood glucose (mg/dl) | Insulin dose (units) | Explanation | Insulin dose (units) | Explanation |
| < 70 | Treat | Treat hypoglycemia | Treat | Treat hypoglycemia |
| 71-100 | 10 | Prandial = 12<br>Correction = -2 | 0 | Prandial = 0<br>Correction = 0 |
| 101-150 | 12 | Prandial insulin dose | 0 | Prandial = 0<br>Correction = 0 |
| 151-200 | 14 | Prandial = 12<br>Correction = 2 | 2 | Prandial = 0<br>Correction = 2 |
| 201-250 | 16 | Prandial = 12<br>Correction = 4 | 4 | Prandial = 0<br>Correction = 4 |
| 250-300 | 18 | Prandial = 12<br>Correction = 6 | 6 | Prandial = 0<br>Correction = 6 |
| 301-350 | 20 | Prandial = 12<br>Correction = 8 | 8 | Prandial = 0<br>Correction = 8 |
| 351-400 | 22 | Prandial = 12<br>Correction = 10 | 10 | Prandial = 0<br>Correction = 10 |
| > 400 | Notify MD | | Notify MD | |

**Fig. 1.1** Building an insulin regimen: 50-year-old man with 10-year history of Type 2 diabetes is admitted for a right foot cellulitis and IV antibiotic therapy. As an outpatient he is on 36 units of glargine insulin before bed along with metformin and glimeperide. His Hgb A1c = 7.9%. His appetite is fine. You plan to stop his oral agents and continue with insulin therapy to control his blood glucose. You opt to continue his glargine at 36 units qHS. You now need to calculate his short-acting bolus insulin dosing. Based on his basal dose of 36 units you estimate his initial prandial insulin requirement to also be 36 units which you order as 12 units before each meal. Since he is not eating at bedtime, he needs no prandial dose at bedtime. His total daily dose of insulin is 72 units. Utilizing the rule of 1800 you estimate his correction factor to be 25 (1800/72 = 25). In other words, 1 unit of insulin will lower his blood glucose by 25 mg/dL and 2 units should lower his blood glucose by 50 mg/dL. This correction is added to the prandial dose as needed

an insulin pump. The first decision that must be made is whether the patient is able to continue on their insulin pump during their hospitalization. If the answer is no, then an alternative insulin regimen must be prescribed. In order to make an appropriate decision regarding the use of insulin pumps, one must understand the basics of how an insulin pump works and what it will and will not do. An insulin pump utilizes only short-acting insulin. Small amounts of insulin are administered by the pump continuously via a small cannula that the patient places subcutaneously. This insulin acts as the background or basal insulin. The rate of insulin delivery is programmed into the pump by the user. Because the programmed rate of insulin delivery can be different at different times of the day, there is a greater ability to match the supply of basal insulin with the demand. Additional insulin is administered from the pump whenever the patient eats. This insulin bolus or prandial insulin is usually based upon the amount of carbohydrate which will be consumed. The patient needs to assess the amount of carbohydrate that they will eat, enter that information into the pump which then calculates the appropriate amount of insulin for that meal. The patient then instructs the pump to administer the insulin. In addition, the patient can instruct the pump to deliver a bolus of insulin to correct for high blood glucose levels, either in conjunction with or separate from a prandial dose of insulin, based on a previously programmed correction factor. Thus, while the insulin is administered by the pump, the amount of insulin to be delivered is determined based on the amount of carbohydrate that is to be consumed and the level of blood glucose. Both of these factors must be assessed by the patient and programmed into the pump and

| | Before breakfast, lunch and supper | | Before bedtime | |
|---|---|---|---|---|
| Blood glucose (mg/dl) | Insulin dose (units) Treat | Explanation | Insulin dose (units) Treat | Explanation |
| < 70 | | Treat hypoglycemia | | Treat hypoglycemia |
| 71-100 | 5 | Prandial = 6 Correction = -1 | 0 | Prandial = 0 Correction = 0 |
| 101-150 | 6 | Prandial insulin dose | 0 | Prandial = 0 Correction = 0 |
| 151-200 | 7 | Prandial = 6 Correction = 1 | 1 | Prandial = 0 Correction = 1 |
| 201-250 | 8 | Prandial = 6 Correction = 2 | 2 | Prandial = 0 Correction = 2 |
| 250-300 | 9 | Prandial = 6 Correction = 3 | 3 | Prandial = 0 Correction = 3 |
| 301-350 | 10 | Prandial = 6 Correction = 4 | 4 | Prandial = 0 Correction = 4 |
| 351-400 | 11 | Prandial = 6 Correction = 5 | 5 | Prandial = 0 Correction = 5 |
| > 400 | Notify MD | | Notify MD | |

**Fig. 1.2** Building an insulin regimen: 50-year-old man with 8-year history of Type 2 diabetes is admitted for a right foot cellulitis and IV antibiotic therapy. As an outpatient he is on metformin, glyburide, and pioglitazone. His Hgb A1c = 8.2%. His appetite is fine. You plan to stop his oral agents and start insulin therapy to control his blood glucose. His weight is 90 kg. You opt to start detemir insulin at 18 units (0.2 × 90 kg) qHS. You now need to calculate his short acting bolus insulin dosing. Based on his basal dose of 18 units you estimate his initial prandial insulin requirement to also be 18 units which you order as 6 units before each meal. Since he is not eating at bedtime, he needs no prandial dose at bedtime. His total daily dose of insulin is 36 units. Utilizing the rule of 1800 you estimate his correction factor to be 50 (1800/36 = 50). In other words, 1 unit of insulin will lower his blood glucose by 50 mg/dL. This correction is added to the prandial dose as needed

then the patient must instruct the pump to deliver the dose. In addition, insulin pumps also have safety features which will trigger alarms for various problems, such as the pump running low on insulin, a lack of insulin delivery or if the pump disconnects from the patient. Therefore, for patients to remain on the pump they must be well enough to calculate their insulin needs, program that information into the pump, and be able to troubleshoot any alarms. If there is any question about a patient's ability to perform all these tasks, then the pump should be discontinued and subcutaneous insulin started. In switching somebody from an insulin pump to subcutaneous insulin, the amount of basal insulin that is required is usually slightly greater when administered as a subcutaneous injection of insulin rather than from the pump. As an initial dose, one can substitute the amount of basal insulin administered over 24 h with an equal dose of a long-acting basal insulin (glargine or detemir) administered subcutaneous. The bolus insulin can be calculated as previously described. These doses can then be adjusted as needed.

## Intensive Care Unit Insulin Management

It is well recognized that the degree of glycemic control in critically ill patients does correlate with patient mortality. Numerous studies have evaluated the question of glycemic control and patient outcomes in the intensive care unit (ICU) setting [18, 19, 24]. Yet these studies are limited since they are observational studies and do not

identify causation. The fundamental question is whether improved glycemic control will lead to improved patient outcomes. Van den Berghe evaluated over 1,500 patients in a surgical ICU in a prospective randomized controlled trial [25]. Conventional therapy required starting insulin when the blood glucose exceeded 215 mg/dL and the intensively treated group started insulin when the blood glucose exceeded 110 mg/dL. The goal for blood glucose control in the intensively treated group was between 80 and 110 mg/dL. The mean morning blood glucose in the conventional group was 153 compared to 103 in the intensively treated group. Results demonstrated a dramatic decrease in mortality as well as sepsis, the need for dialysis and the need for blood transfusion.

The Nice-Sugar (The Normoglycemia in Intensive Care Evaluation—Survival Using Glucose Algorithm Regulation) trial was designed to see if even tighter glycemic control would prove of further benefit [26]. Over 6,100 patients were randomized to receive either conventional insulin treatment with the goal of achieving a blood glucose level of under 180 mg/dL vs. intensive insulin treatment with a goal of achieving a blood glucose level between 81 and 108 mg/dL. The study was performed utilizing both surgical as well as medical patients in the ICU. The mean time-weighted blood glucose level achieved in the conventional treated group was 144 mg/dL compared to 115 mg/dL in the intensively treated group. Patients in the intensively treated group had an increased mortality with an odds ratio of 1.14. This increased mortality was seen in both surgical and medical patients. While there was a trend for an even worse mortality in the intensively treated surgical patients compared to intensively treated medical patients, this difference was not statistically significant.

Based on this data as well as numerous other studies, the American Association of Clinical Endocrinologists recommends that insulin therapy should be initiated for persistent hyperglycemia of at most 180 mg/dL. Once insulin therapy is started the blood glucose goal is between 140 and 180 mg/dL. In critically ill patients, intravenous insulin infusion utilizing a validated insulin infusion protocol is the preferred method of administration [19]. Numerous IV insulin infusion protocols are available. A sample protocol is shown in Fig. 1.3. This protocol takes into account not only the level of blood glucose, but also the rate of change.

## Perioperative Insulin Management

The goal of insulin management during the hospital stay is to maintain appropriate glycemic control with the avoidance of hypoglycemia. Because the patient is not able to recognize and complain of hypoglycemic symptoms during the perioperative period the issue of safety is heightened. In addition, since the perioperative period is relatively short, the need for tight glycemic control is less critical. Maintaining the blood glucose between 140 and 180 mg/dL during the perioperative period should meet both of these requirements. Patients who are on an IV insulin infusion prior to surgery should be continued on this therapy through the perioperative period. The IV infusion allows the greatest degree of control over the blood glucose as well as a high degree of safety. Blood glucose should be monitored every hour and the rate of insulin infusion should be adjusted based upon an accepted algorithm, such as the one outlined in Fig. 1.3.

Patients who are on subcutaneous insulin prior to surgery can be maintained on a subcutaneous insulin regimen but with some modifications. Patients are frequently on basal insulin, such as glargine or detemir. These insulins provide basal or background insulin coverage. Therefore, when the patient is NPO and on an appropriate dose of basal insulin, one would expect that no adjustment in the dose is needed. But, because of the variability in blood glucose levels from day to day even an appropriate dose of basal insulin can occasionally induce hypoglycemia. A hypoglycemic event, either because of its severity or because of the need for oral glucose, can lead to either delay or cancelation of planned surgery. As such, the preferred approach is to decrease the dose of basal insulin prior to surgery by 20% thus affording a greater degree of assurance of avoiding a hypoglycemic event [27]. High blood

## Insulin Infusion Algorithm for Critically Ill Intraoperative and Medical ICU Patients (Target BG 140-180 mg/dl)

**Insulin dose adjustments using this algorithm do not replace sound medical judgment.**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **<100** | Hold drip and give ½ - 1 amp 50% glucose and check BG every 30 minutes until >140 mg/dl and then re-initiate drip at 50% previous rate | | | | | | | |
| **Current BG level (mg/dl)** | **Previous Blood Glucose (mg/dl)** | | | | | | | |
| | **<100** | **100-140** | **141-180** | **181-200** | **201-250** | **251-300** | **301-400** | **>400** |
| **101-140** | ↓ rate by 1unit/hr | ↓ rate by 25% or 0.5 units/hr* | | ↓ rate by 50% or 2 units/hr* | | | ↓ rate by 75% or 2 units/hr* | |
| **141-180** | No Change | | | | ↓ rate by 50% or 2 units/hr* | | | |
| **181-200** | ↑ rate by 1 unit/hr | ↑ rate by 0.5 units/hr | | ↑ rate by 25% or 1 unit/hr* | No Change | ↓ rate by 25% or 2 units/hr* | | |
| **201-250** | ↑ rate by 25% or 2 units/hr* | | | ↑ rate by 25% or 1 unit/hr* | | | ↑ rate by 1 unit/hr | No Change |
| **251-300** | ↑rate by 33% or 2.5 units/hr* | | ↑ rate by 25% or 1.5 units/hr* | ↑ rate by 25% or 1 unit/hr* | ↑ rate by 1 unit/hr | ↑ rate by 1.5 units/hr | ↑ rate by 25% or 2 units/hr* | No Change |
| **301-400** | ↑ rate by 40% or 3 units/hr* | | | | | | | |
| **>400** | ↑ rate by 50% or 4 units/hr* | | | | | | | |

- ***Whichever is greater change**

↓

This algorithm assumes hourly BG checks during insulin dose titration.

↓

- If BG in desirable range (140-180 mg/dl) for 4 hours, decrease frequency of BG checks to every 2 hours while BG stays in target.
- If experiencing unexplained hypoglycemia or hyperglycemia, investigate and correct causative factors.
- If there is any significant change in glycemic source (i.e., parenteral, enteral or oral intake), expect to make insulin adjustment.

↓

**Common reasons to discontinue insulin infusion:**

- Patient tolerating at least 50% of normal oral intake or enteral feedings
- Clinically appropriate to transfer patient to a unit that does not do insulin infusions
- Patient on stable regimen of TPN with most of insulin already in TPN solution

↓

**Two hours before discontinuing insulin infusion, initiate alternative glycemic management:**

- For patients with type 1 diabetes or those with type 2 diabetes previously controlled on insulin: If NPO, initiate basal subcutaneous insulin (glargine, detemir or NPH) at 80% of the insulin administered over the previous 24 hours by insulin infusion. If the patient is taking more than 50% of usual oral or enteral intake, give 50% of insulin dose as basal insulin based on previous 24 hours of insulin infused or 0.25 units/kg and initiate pre-meal bolus and correction dose to maintain BG in target. Another alternative is to resume pre-hospital insulin regimen. Insulin pump patients can resume pump use based on hospital policy.
- For patients with type 2 diabetes previously treated with oral antidiabetes agents: If patient had good diabetes control previous to hospitalization, a return to oral agent therapy may be considered based on postoperative clinical status; if pre-hospital control was inadequate, plan for discharge on subcutaneous insulin.



**Fig. 1.3** Intravenous insulin infusion protocol. (Copyright 2009 by Joslin Diabetes Center. All rights reserved. Excerpted with permission from Joslin's Guideline for Inpatient Management of Surgical and ICU Patients with Diabetes. Refer to Joslin's Web site (www.joslin.org) for updates to its Clinical Guidelines)

glucose levels on the morning of surgery can be corrected through the use of a correction dose of short-acting insulin. The bolus dose of insulin comprises the prandial insulin component as well as the correction component as discussed previously. Since the patient is NPO, the prandial dose is zero. The correction dose is not affected. Thus, the dose of bolus insulin includes only the correction dose. This dose should be the same as the prebed insulin scale since the prandial dose of insulin at bedtime is zero. Therefore, the prebed insulin scale can be used when the patient is NPO (see Figs. 1.1 and 1.2).

For patients who are not on basal insulin but instead are treated with NPH insulin, adjustments are also needed. In theory, a dose of NPH given before supper or bedtime would not need to be reduced since the duration of action of the NPH is short enough that most of the action of the insulin is gone by morning. Even though the patient is NPO overnight, their food intake during the night is no different than it is on other nights—people are routinely NPO overnight only to eat again in the morning. Yet, the dose of NPH is often decreased by 20% because of the variability of blood glucose and the desire to avoid hypoglycemia as previously described regarding the use of basal insulin [25]. The morning dose of NPH needs to be decreased since NPH insulin does have a peak and will induce hypoglycemia in a patient who is not eating. The dose needs to be decreased by at least 50% [28]. One must remember that patients with Type 1 diabetes need continuous background insulin even when not eating to avoid the production of ketones and the risk of developing DKA. Therefore, one must never completely hold the dose of the morning NPH and use only short-acting insulin in a patient with Type 1 diabetes. The adjustment to the dose of bolus insulin is identical to that for patients who are on basal–bolus insulin regimen. The prandial dose of insulin is zero and only the correction dose of bolus insulin is used.

For patients who are on a premixed insulin, one should calculate the amount of NPH insulin and the amount of short-acting insulin in each dose. One should then proceed as if the patient were on NPH insulin along with short-acting insulin. The dose of NPH insulin should be adjusted as noted above and administered. Again, the dose of short-acting insulin should be held since the patient is NPO and correction scale should be ordered in case the blood glucose is unacceptably high and needs to be adjusted. A summary of insulin adjustment in the perioperative period can be found in Table 1.3.

**Table 1.3** Adjustment to insulin preoperatively

| Insulin type | Insulin | Adjustment |
|---|---|---|
| Basal | Detemir (Levemir)<br>Glargine (Lantus) | 20% reduction |
| Intermediate | NPH (Humulin N)<br>(Novolin N) | 20% reduction the night before surgery<br>50% reduction the morning of surgery |
| Short-/rapid-acting | Aspart (Novolog)<br>Glulisine (Apidra)<br>Lispro (Humalog)<br>Regular (Humulin R)<br>(Novolin R) | Prandial dose = 0<br>Correction dose unchanged (can use HS scale) |

## Discharge Planning

Prior to discharge, one must assess whether the patient will need additional education or skill training in order to be discharged safely. The earlier discharge planning begins the less likelihood that a patient's discharge will be delayed due to an issue with their diabetes. This situation is common for patients who were not on insulin at the time of their admission but will need to be discharged on insulin either because their diabetes was under poor control prior to hospitalization and insulin therapy was needed or because the patient's illness has exacerbated their glycemic control and insulin will be needed at least temporarily. Regardless of the cause for insulin therapy, once it becomes clear that the patient will need insulin therapy after discharge appropriate diabetes education should be instituted. Another common situation when education will be needed is the patients who were unaware that they had diabetes prior to hospitalization and the diagnosis is made during their hospitalization.

The goal of diabetes teaching during hospitalization is to provide the patients with the basic skills necessary to be safely discharged. Appropriate follow-up should be arranged with either their primary care physician or an endocrinologist as well as with a certified diabetes educator for further diabetes education.

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