Perioperative Management of Diabetes Mellitus

View online at http://pier.acponline.org/physicians/diseases/periopr879/periopr879.html

Module Updated: 2012-10-01
CME Expiration: 2015-10-01

Author
Susan E. Spratt, MD

Table of Contents
1. Elements of Risk ................................................................. 2
2. Whom and How to Assess ..................................................... 5
3. Interventions to Decrease Risk ............................................. 13
4. Patient Counseling ............................................................. 24
5. Follow-up ........................................................................... 27
References ............................................................................. 29
Glossary ................................................................................. 33
Tables ..................................................................................... 35
Figures .................................................................................... 44

Quality Ratings: The preponderance of data supporting guidance statements are derived from:

A level 1 studies, which meet all of the evidence criteria for that study type;
B level 2 studies, which meet at least one of the evidence criteria for that study type; or
C level 3 studies, which meet none of the evidence criteria for that study type or are derived from expert opinion, commentary, or consensus.

Study types and criteria are defined at http://smartmedicine.acponline.org/criteria.html

Disclaimer: The information included herein should never be used as a substitute for clinical judgement and does not represent an official position of the American College of Physicians. Because all PIER modules are updated regularly, printed web pages or PDFs may rapidly become obsolete. Therefore, PIER users should compare the module updated date on the official web site with any printout to ensure that the information is the most current available.

CME Statement: The American College of Physicians is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing education for physicians. The American College of Physicians designates this enduring material for a maximum of 1 AMA PRA Category 1 Credit™. Physicians should claim only credit commensurate with the extent of their participation in the activity. Purpose: This activity has been developed for internists to facilitate the highest quality professional work in clinical applications, teaching, consultation, or research. Upon completion of the CME activity, participants should be able to demonstrate an increase in the skills and knowledge required to maintain competence, strengthen their habits of critical inquiry and balanced judgement, and to contribute to better patient care. Disclosures: Susan E. Spratt, MD, current author of this module, is a consultant and speaker for Sanofi Aventis and Novo Nordisk. Deborah Korenstein, MD, FACP, Co-Editor, PIER, has no financial relationships with pharmaceutical companies, biomedical device manufacturers, or health-care related organizations. Richard B. Lynn, MD, FACP, Co-Editor, PIER, has no financial relationships with pharmaceutical companies, biomedical device manufacturers, or health-care related organizations.

PIER is copyrighted ©2014 by the American College of Physicians. 190 N. Independence Mall West, Philadelphia, PA 19106, USA.
1. Elements of Risk

Recognize that diabetes mellitus is a major risk factor for serious perioperative complications.  

1.1 Appreciate that patients with diabetes are at increased risk for perioperative complications and morbidity, including cardiovascular and infectious complications and DKA.

Recommendations

- Be aware that patients with diabetes are at risk for developing perioperative complications that are associated with high rates of morbidity and mortality, including:
  - Hyperglycemia
  - Hypoglycemia
  - DKA
  - Postoperative infections such as wound and urinary tract infections
  - Cardiac complications such as MI and death (see module Preoperative Cardiac Risk Assessment)
  - Postoperative stroke

Evidence

- In a prospective cohort study of 520 patients undergoing elective surgery (general, vascular, thoracic, and head and neck surgery), abnormal glucose levels were found in 69% of patients with diabetes compared to 13% in those without diabetes ($P<0.0001$) (1).
- A therapeutic trial showed that higher glucose levels postoperatively were associated with an increased rate of infection and mortality (2).
- A 2003 American Diabetes Association review stated that the mortality rate associated with DKA is <5% in younger individuals, and 15% for patients with hyperosmolar nonketoacidosis (3).
- In a retrospective chart review of 338 patients with a discharge diagnosis of DKA, the mortality rate for older individuals (>65 years) was 22% (4).
- In a randomized, controlled trial of 1548 patients assigned to either intensive or conventional insulin therapy in the postoperative period, the rate of hypoglycemic episodes (defined as <40 mg/dL or <2.2 mmol/L) among the intensive insulin treatment group was 5% (39 out of 765). Only 2 patients developed symptoms of agitation and diaphoresis, but no patient suffered from seizures or coma (2).
- In an observational study of 2402 CABG surgeries done between 1977 and 1991, there were 125 episodes of wound infection (5%). Only steroid use and diabetes were identified as predictor variables for postoperative wound infections (5).
- In a prospective cohort of 561 patients undergoing lower extremity vascular surgery, 4% of patients developed postoperative surgical wound infections. The presence of diabetes was associated with development of wound infections (6).
- In a case-controlled study of patients with deep sternal site infection after CABG, several variables were identified as predicting wound infections, including diabetes with preoperative glucose >110 mg/dL (OR, 3.7) and 125 mg/dL (OR, 10.2) (7).
- In a retrospective cohort study of 254 consecutive patients referred for nuclear cardiology testing before vascular surgery, investigators found that if one or two clinical predictors (ventricular ectopy, Q waves on ECG, advanced age, diabetes, or angina) were present, there was a 15.5% chance of having early postoperative ischemic events (CI, 7% to 21%). For patients with none of
these risk factors, there was a low risk for cardiovascular events or death. If a patient had three or more risk factors, the risk for cardiovascular events was high (50%). This risk estimate for the intermediate group was further refined using thallium scintigraphy (8).

- In a validated prospective cohort study of 1081 patients undergoing vascular surgery, history of MI (abnormal Q waves or by history), angina, aged >70 years, diabetes, history of HF, or previous coronary revascularization in combination with an abnormal dipyridamole thallium scintography result predicted postoperative cardiac events (9).

- From a validated prospective cohort study of 4315 patients undergoing elective noncardiac surgery, investigators determined a six-variable, equally weighted scoring system that was more accurate in predicting major cardiac events in patients aged ≥50 years hospitalized for at least 2 days. The six variables included preoperative use of insulin, history of HF, history of ischemic heart disease, history of cerebrovascular disease, significant renal impairment (creatinine level >2.0 mg/dL or 177 mmol/L), and major surgery. Each of these variables was associated with an adjusted OR between 1.9 and 3.0 for major cardiac events (10).

- In a prospective cohort study (1996 to 2001), 16,184 patients undergoing cardiac surgery were monitored for development of postoperative stroke. Stroke occurred in 4.6% of patients and was independently associated with history of diabetes in multivariable analysis (11).

- In a retrospective analysis of patients undergoing cardiac surgery, diabetes was associated with major complications such as bacterial endocarditis and sternal osteomyelitis (12).

- In a prospective study of 5031 patients undergoing noncardiac surgery (1995 to 2000), 3.2% developed surgical site infections. Diabetes was an independent risk factor for development of the surgical site infection by multivariable analysis (13).

- In a retrospective study of 197,461 patients who underwent lumbar fusion (1998 to 2003), the 11,000 patients with diabetes (5.6% of the cohort) had an increased risk of postoperative infection, need for transfusion, pneumonia, and longer duration of hospital stay (14).

- A prospective trial of patients undergoing carotid endarterectomy showed a higher rate of stroke and death within 30 days of surgery in patients with diabetes (4.5% vs. 1.5% in patients without diabetes (15).

- An observational study of 3184 noncardiac surgery patients reported that perioperative hyperglycemia is correlated with increased length of ICU and hospital stay, complications, and mortality after noncardiac surgery. Hospital complications more common in patients with hyperglycemia included sepsis, renal failure, UTI, and MI (16).

- A prospective, observational study of 5050 patients undergoing CABG noted that mortality was higher in patients with diabetes and in patients without diabetes who have postoperative hyperglycemia (17).

**Rationale**

- Patients with diabetes are more likely to have high glucose levels than those without diabetes.

- Elevated glucose levels are associated with higher risk for postoperative infections and death.

- Patients with type 1 diabetes require insulin (± glucose) even when glucose levels are in the normal range. Inadequate insulin therapy can result in serious complications, such as DKA.

- Hypoglycemia can be caused by overly aggressive glucose reduction therapy, insufficient glucose intake, or increased glucose use perioperatively and can lead to seizures, coma, and death.

- Unrecognized hypoglycemia can cause severe neurologic sequelae.

- Rates of postoperative wound infections are much higher in patients with diabetes than in those without.
Patients with diabetes are at higher risk for perioperative HF, MI, stroke, and cardiac death than those without diabetes.

Comments

- The CDC estimates that 25.8 million people (11.3% of Americans aged over 20 years) have diabetes; 7 million remain undiagnosed.

- The Canadian Heart Health Survey (1986 to 1992) found that 5% of Canadians have diabetes (19). In a cohort of patients with diabetes, approximately 50% required surgery during their lifetime (20).
2. Whom and How to Assess

Assess all patients with diabetes before surgery with careful history, physical exam, lab testing, and additional cardiac testing in selected patients.

2.1 Identify patients who may be at risk for developing DKA as part of the routine preoperative evaluation.

Recommendations

- Identify patients with type 1 diabetes and insulin-deficient type 2 diabetes.
- Recognize that all patients with type 1 diabetes are at risk for developing postoperative DKA.
- In patients with type 1 diabetes, look for DKA by testing serum ketones, bicarbonate level, and anion gap, and if these tests are abnormal, postpone surgery and treat with insulin and fluids.
- Consider patients with type 2 diabetes and any of the following characteristics to be prone to DKA:
  - Young age (aged <40 years)
  - Use of insulin alone to control hyperglycemia
  - BMI <25 kg/m²
  - History of DKA
  - Family history of type 1 diabetes
  - History of pancreatectomy or pancreatic dysfunction
- Recognize that stress and infection can precipitate hyperglycemia.
- Recognize that the administration of pharmacologic agents such as vasopressors or glucocorticoids can cause iatrogenic hyperglycemia.
- Recognize that withholding insulin can cause hyperglycemia and DKA.
- Recognize that pancreatic surgery can increase the risk of derangement of glycemic control in all patients, regardless of whether a diagnosis of diabetes has been made.

Evidence

- Mainly consensus.

Rationale

- All patients with type 1 diabetes are at risk for developing DKA.
- DKA can occur in patients with type 2 diabetes, but is relatively uncommon.
- Proper identification of patients who may be prone to DKA will alter postoperative management and lab testing.
- Patients with type 1 diabetes and insulin-deficient type 2 diabetes are prone to developing DKA, especially if their insulin is withheld for a prolonged period (even as short as 8 hours).

Comments

- Withholding basal insulin in patients with type 1 diabetes or insulin-deficient type 2 diabetes can cause hyperglycemia, DKA, and death.
- Preoperative recognition of which patients require basal insulin can prevent hyperglycemia and DKA and thus, reduce the length of hospital stay and complications.
The 2005 to 2008 National Health and Nutrition Examination Survey documented that 13.7% of people aged between 45 and 64 years and 26.9% of people aged over 64 years with diabetes do not know that they have diabetes.

2.2 Assess for patient-related risk for hypoglycemia.[C]

Recommendations
- Ask about:
  - Previous episodes of glucose readings <70 mg/dL (4.0 mmol/L)
  - Symptoms of lightheadedness, diaphoresis, and nausea that are ameliorated with eating
- Determine the frequency, severity, and awareness of the hypoglycemic episodes, including:
  - Loss of consciousness, which denotes severe hypoglycemia
  - Patient awareness of minor symptoms, such as agitation, fatigue, lightheadedness, and feeling cold
- Determine the factors that may explain the episodes of hypoglycemia, such as:
  - Low intake of calories at specific times
  - Excessive exercise
  - Excessive use of insulin or sulfonylureas corresponding to times of hypoglycemia
- Determine if the patient's home dose of insulin is accurate:
  - Ascertain how the patient takes insulin at home; inquire if the glucose level is normal or low if insulin is not given
  - Ascertain whether the patient experiences hypoglycemia if a meal is skipped

Evidence
- A related prospective cohort study of outpatients showed that low self-monitored blood glucose levels predicted severe episodes of hypoglycemia (stupor or unconsciousness) among patients with type 1 diabetes (21).
- Errors in administration of insulin account for 13% of medication errors in the U.S. (22; 23).

Rationale
- The patient's baseline glycemic control may predict postoperative control and potential risk for hypoglycemia.
- Identifying factors that may be associated with hypoglycemia will allow the physician to correct an underlying problem in diabetes management and thereby reduce the risk for postoperative hypoglycemia when outpatient drug therapy is resumed.
- If the patient skips insulin if the blood glucose level is low, or if the patient has hypoglycemia if a meal is skipped, then it is likely that the home insulin dose is too high.
- Identifying an accurate insulin dose for each patient reduces hypoglycemia and hyperglycemia during hospitalization.

2.3 Screen nondiabetic patients undergoing cardiac surgery with preoperative HbA1c.[B]

Recommendations
- Check HbA1c in all patients undergoing cardiac surgery, even if diabetes has not been diagnosed.
- Consider checking HbA1c in all patients undergoing major noncardiac surgery, or confirm that fasting glucose is under 100 mg/dL in all patients with no diabetes diagnosis undergoing major surgery. If glucose is over 100 mg/dL, check HbA1c to assess for overall glucose control.

Evidence
• An observational study of 7310 patients undergoing cardiac surgery found that 5.2% had undiagnosed diabetes. Patients with undiagnosed diabetes had higher rates of complications and death than either patients with known diabetes or nondiabetics (24).

• According to the Third National Health and Nutrition Examination Survey (1988 to 1994), 50% of patients with diabetes are not aware of their diagnosis (18).

• An observational study of 3184 noncardiac surgery patients assessed that perioperative hyperglycemia is correlated with increased length of ICU and hospital stay, complications, and mortality after noncardiac surgery. Hospital complications more common in patients with hyperglycemia included sepsis, renal failure, UTI, and MI (16).

• Patients with diabetes are at increased risk for postoperative surgical site infection (25).

• A prospective, observational study of 5050 patients undergoing CABG noted that mortality was higher in patients with diabetes and in patients without diabetes who have postoperative hyperglycemia (17).

Rationale
• Diabetes increases the risk for postoperative wound infection, hospital complications, and mortality. Twenty-six million Americans have diabetes and one-third are unaware that they have it. Given the high prevalence of diabetes and increased risk for postoperative complications, it is important to properly diagnose and treat patients who have diabetes and are undergoing surgery.

2.4 Assess overall health status of patients with diabetes when determining the patient-related risk for perioperative cardiac complications.

Recommendations
• Determine the level of risk for having a perioperative cardiac complication using the Revised Cardiac Risk Index and the ACCF/AHA guidelines for perioperative cardiovascular evaluation for noncardiac surgery.
• Consider whether the patient requires further noninvasive cardiac testing as part of the preoperative evaluation.
• See module Preoperative Evaluation.
• See module Preoperative Cardiac Risk Assessment.

Evidence
• In a retrospective cohort study of 254 consecutive patients referred for nuclear cardiology before vascular surgery, investigators found that if one or two clinical predictors (ventricular ectopy, Q waves on ECG, advanced age, diabetes, or angina) were present, patients had a 15.5% chance of having early postoperative ischemic events (CI, 7% to 21%). This risk estimate was further refined using thallium scintography (8).
• In a validated prospective cohort study of 1081 patients undergoing vascular surgery, history of MI (abnormal Q waves on ECG or by history), angina, age >70, diabetes, history of HF, or previous coronary revascularization in combination with an abnormal dipyridamole thallium scintigraphic test result predicted increased postoperative cardiac events (9).
• From a validated prospective cohort study of 4315 patients undergoing elective noncardiac surgery, investigators determined a six-variable, equally weighted scoring system for cardiac risk stratification. This Revised Cardiac Risk Index was more accurate in predicting major cardiac events in patients ≥50 years admitted to hospital for at least 2 days as compared to the Goldman, Detsky, and American Society of Anesthesiologist risk indices (10).
• The ACCF/AHA guidelines recommend standard risk assessment before surgery (26).
In a prospective study of 1351 patients undergoing vascular surgery, dobutamine stress ECG was helpful to further risk stratify patients who were not able to take perioperative β-blockers (27).

In a prospective cohort study of patients referred for exercise or dobutamine stress ECG, 236 patients with negative results were followed for 25 ± 7 months. There was no difference found in cardiac death rates among those with and without diabetes (4.2% vs. 5.6%); however, nonfatal MI was higher in the group with negative test results and diabetes compared with those with negative test results without diabetes (6.7% vs. 1.4%, P<0.05) (28).

**Rationale**

- Patients with diabetes are at significant risk of having CAD and postoperative cardiac complications.
- The Revised Cardiac Risk Index is a validated risk scoring system for low-risk individuals undergoing elective surgery who are aged >50 years and intended to stay in the hospital for at least 2 days.
- The ACCF/AHA guidelines for perioperative cardiovascular evaluation for noncardiac surgery provide algorithms for risk stratification that incorporate history, physical exam, lab tests, and further cardiac testing for all patients undergoing emergent and elective noncardiac surgery.

**Comments**

- The Revised Cardiac Risk Index was derived from a cohort of mostly lower-risk individuals undergoing elective surgery and therefore may not be generalized to emergency surgery patients.

### 2.5 Determine the type of surgical procedure and planned anesthesia technique.

**Recommendations**

- Assess whether the patient will undergo minor or major surgery to determine the desired target glucose range and the strategy to control hyperglycemia:
  - A minor surgical procedure is of short duration with minimal fluid shifts or tissue dissection
  - Major surgery is a procedure that is long and complex, such as:
    - Intra-abdominal or intrathoracic procedures
    - Cardiac surgery
    - Major vascular surgery
    - Multiple trauma surgery
    - Prolonged neurosurgery (>4 hours)
    - Transplantation surgery
- Determine if the patient will be undergoing epidural anesthesia or general anesthesia.
- See module Preoperative Evaluation.

**Evidence**

- In a prospective cohort study, 150 patients undergoing either anesthesia without surgery, surface surgery, thoracic surgery, or intra-abdominal surgery had serial blood glucose levels measured. The largest rises in blood glucose were found in the patients undergoing intra-abdominal procedures followed by thoracic procedures. Body surface surgery and anesthesia without surgery had the smallest changes in glucose levels (29).
- In a similar prospective cohort study of 36 patients (6 of whom had diabetes), no difference existed in the degree of hyperglycemia across the different types of surgery among those with and without diabetes (30).
- A group of 40 elderly patients (20 had type 2 diabetes) scheduled to undergo elective cataract surgery were randomly allocated to receive standard general anesthetic or local anesthetic. Serial levels of glucose and cortisol increased in general anesthetic patients (those with diabetes and
those without) throughout surgery compared with preoperative levels but returned to normal within 4 hours postprocedure. In the local anesthesia group, the serum glucose and cortisol did not change significantly (31). Although these investigators did not find a difference in the degree of glucose abnormality in patients with or without diabetes, the sample sizes may have been too small to detect a difference.

- Physiologic studies have shown that epidural anesthesia has less impact on glucoregulatory hormones compared to general anesthesia (32).

Rationale

- Studies have found that the magnitude of surgery affects the extent of hyperglycemia.
- Minor surgeries such as dilatation and curettage, mastectomy, and hernia repair cause minimal changes in glucose levels compared to intra-abdominal or thoracic procedures; major surgeries that are long and complex require insulin infusions to maintain meticulous control of glucose levels.
- Epidural anesthesia may be less likely to cause stress hyperglycemia.
- Specific types of surgery are associated with certain types of wound infections among patients with diabetes; open-heart surgery portends a higher risk for developing bacterial endocarditis or sternal osteomyelitis in patients with diabetes.

Comments

- Patients who undergo intra-abdominal surgery, cardiac surgery, intrathoracic surgery, vascular surgery, transplant surgery, prolonged neurosurgery, and multiple trauma surgery are at increased risk for hyperglycemia and infections. These patients often will require close glucose monitoring and possibly iv insulin perioperatively to maintain tight glycemic control (29).

2.6 Assess preoperative glucose levels in all patients with diabetes to stratify their risk for postoperative wound infections and in order to optimize preoperative therapy.

Recommendations

- Obtain serum glucose levels (pre-meal or fasting) at the time of the preoperative assessment for the purposes of risk stratification for postoperative wound infections and to determine if additional medical therapy may be needed upon discharge.
- Consider postponing elective surgery if glucose levels are high (>220 mg/dL or >12 mmol/L) or if patients have signs or symptoms of dehydration due to hyperglycemia until glucose levels are normalized and symptoms have resolved.
- See figure HbA1c Guidance.

Evidence

- In patients with diabetes undergoing abdominal or cardiac surgery, preoperative glucose level >220 mg/dL increased the risk of nosocomial infection 2.7-fold over those patients with diabetes whose blood glucose level never increased above 220 mg/dL (33).
- In a case-control study of patients with deep sternal site infection after CABG, variables were identified as predicting wound infections. Diabetes with a preoperative glucose level >110 mg/dL increased the risk for mediastinitis three-fold, and diabetes with a preoperative glucose level >125 mg/dL increased the risk 10-fold (7).
- In a prospective cohort study of 520 patients undergoing elective surgery (general, vascular, thoracic, and head and neck surgery), laboratory and historical features were assessed. In patients with diabetes, abnormal glucose levels were found in 69% compared to 13% in those without diabetes (P<0.0001) (1).
A systematic review of 16 case series of healthy preoperative patients found that serum glucose was abnormal in up to 5% of patients and rarely led to changes in clinical management (34).

Patients with a preoperative blood glucose level >150 mg/dL undergoing knee or hip surgery had a 10% risk of pulmonary embolism (35).

**Rationale**

- Preoperative hyperglycemia increases the risk for postoperative wound infections.
- Patients with diabetes are more likely to have abnormal preoperative glucose readings compared to those without diabetes.
- Assess an elevated glucose level at the time of the preoperative assessment in the context of the patient’s dietary intake at that time and their overall glucose control (fasting blood glucose levels over the past 2 weeks).
- A significantly elevated glucose level (>220 mg/dL or >12 mmol/L) may reflect extremely poor control of diabetes or an acute process.

**Comments**

- Although the correlation between hyperglycemia and poor outcomes in surgical patients (especially postoperative infection) is well documented, there have been no published interventional studies of obtaining preoperative glycemic control in regard to outcomes.
- Point-of-care glucose testing (also known as bedside glucose monitoring) is preferred for hospital management of patients with diabetes.
- In all patients with diabetes undergoing purely elective surgery, it seems prudent to obtain blood glucose levels commensurate with outpatient goals (fasting glucose <120 mg/dL and 2-hour postprandial glucose <140 mg/dL).
- To achieve glycemic goals, it may be necessary to intensify the medical regimen, including adding outpatient preoperative insulin.
- In patients undergoing emergency surgery, there is no luxury to obtain tight preoperative glycemic control, but control can be achieved perioperatively with iv insulin.

### 2.7 Determine renal function in all patients with diabetes before surgery

**Recommendations**

- Obtain preoperative serum creatinine level and possibly BUN levels for all patients with diabetes.

**Evidence**

- In a prospective cohort study of 4315 patients undergoing elective noncardiac surgery, renal dysfunction (creatinine level >2.0 mg/dL or 177 mmol/L) was found to be an independent risk factor for postoperative major cardiac complications both in univariate and multivariate analysis (OR, 5.2 [CI, 2.6 to 10.3]) (10).
- In a prospective cohort of 520 patients undergoing elective surgery (general, vascular, thoracic, and head and neck surgery), laboratory and historical features were assessed. In patients with diabetes, abnormal BUN/creatinine levels were found in 38% compared to 19% in those without diabetes (P<0.0003) (1).
- In a study of patients undergoing elective surgery, renal function was found to be more likely abnormal in patients with diabetes in than those without (1); however, in a systematic review of 16 case series of healthy patients, routine testing found that BUN and creatinine levels were abnormal in up to 2.5% of patients but rarely led to changes in perioperative care (34).
• In an observational study of 596 critically ill patients, hypoglycemia occurred in 21%. Hypoglycemia was associated with mortality, respiratory failure, and hemodynamic instability. In addition to diabetes, chronic renal failure was associated with hypoglycemia (36).

Rationale
• Patients with type 1 and type 2 diabetes often have coexisting renal dysfunction.
• The presence of renal disease significantly increases the risk of postoperative cardiac complications.
• Renal dysfunction can affect fluid and electrolyte balance, drug dosing, and postoperative monitoring, as well as affect the safety of radiological and interventional studies with contrast.

2.8 Obtain preoperative urinalysis only in selected situations for diabetic patients; do not obtain routine preoperative urinalysis. 

Recommendations
• Do not obtain a urinalysis to screen for urinary tract infection in asymptomatic patients with diabetes as part of a routine preoperative screening for most surgical procedures.
• Obtain routine preoperative urinalysis screening in all patients undergoing urologic and perhaps orthopedic procedures.
• Obtain a urinalysis in patients with symptoms of urinary tract infection.

Evidence
• In a prospective cohort study of 520 patients undergoing elective surgery (general, vascular, thoracic, and head and neck surgery), laboratory and historical features were assessed. In patients with diabetes, abnormal urinalysis was found in 24% compared to 14% in those without diabetes (P=0.03) (1).
• A systematic review of 16 case series of healthy preoperative patients found that urinalysis was abnormal in 1% to 34% of patients but led to changes in clinical management in only 1% to 2.8% (34).
• In a cost analysis, the cost of routine preoperative urinalysis in patients heading for orthopedic surgery is 500 times greater than the cost of treating additional cases of postoperative wound infections (37).
• In urologic and orthopedic surgery, urinary tract infections may increase the risk of perioperative infections (38; 39).

Rationale
• Asymptomatic pyuria (abnormally increased number of leukocytes in the urine) rarely leads to changes in perioperative management.
• The evidence that pyuria leads to an increased rate of postoperative wound infection among orthopedic patients is controversial.
• The costs of preoperative screening for UTI would far outweigh the costs of treating additional cases of postoperative wound infection.

2.9 Obtain a preoperative ECG to further stratify cardiac risk.

Recommendations
• Screen all patients who have diabetes with a resting 12-lead ECG, specifically looking for:
  • Abnormal Q waves suggesting old MI
  • Cardiac rhythm other than sinus
  • Ventricular or atrial ectopy
• See module Preoperative Evaluation.
• See module Preoperative Cardiac Risk Assessment.

**Evidence**

• In a retrospective cohort study of 254 consecutive patients referred for nuclear cardiology before vascular surgery, investigators found that if one or two clinical predictors existed (ventricular ectopy, Q waves on ECG, advanced age, diabetes, or angina), the patient had a 15.5% chance of having early postoperative ischemic events (CI, 7% to 21%). This risk estimate was further refined using thallium scintography (8).

• In the Eagle criteria for vascular surgery, diabetes and an abnormal ECG predicted risk of postoperative cardiac complications. In a validated prospective cohort study of 1081 patients undergoing vascular surgery, history of MI (abnormal Q waves on ECG or by history), angina, age >70, diabetes, history of HF, or previous coronary revascularization in combination with an abnormal dipyridamole thallium scintigraphic test result predicted increased postoperative cardiac events (9).

• In a validated prospective study of 4315 patients undergoing noncardiac surgery, the investigators found that history of ischemic heart disease defined as abnormal Q waves on ECG or by history was predictive of postoperative cardiac events (10).

• In a prospective cohort study of 520 patients undergoing elective surgery (general, vascular, thoracic, and head and neck surgery), laboratory and historical features were assessed. In patients with diabetes, abnormal ECG was found in 77% compared to 47% in those without diabetes (P<0.0001) (1).

• A Revised Cardiac Risk Index supplemented by age, preoperative ECG, and presence of any type of diabetes predicts long-term survival after major vascular surgery (40).

**Rationale**

• Patients with diabetes are at two to four times higher risk for having coexisting ischemic heart disease and abnormal ECG results.

• ECG may reveal clues to suggest CAD, as patients with diabetes can have atypical or silent symptoms of ischemia.

• ECG abnormalities such as previous MI (abnormal Q waves), ventricular ectopy, or atrial ectopy are variables that have been used in various cardiac risk indices for noncardiac surgery, such as the Revised Cardiac Risk Index and Eagle/L’Italien criteria for vascular surgery.

**Comments**

• If possible, preoperative ECG result should be compared to previous ECG readings to assess important changes over time.
3. Interventions to Decrease Risk

Control perioperative hyperglycemia to reduce rates of infection and mortality.

3.1 Optimize glycemic control before surgery.

Recommendations

- Achieve optimal control before elective procedures (HbA1c <7%, preprandial glucose <130 mg/dL, and peak postprandial glucose <180 mg/dL).
- Recognize that glycemic goals may be less stringent in patients with frequent profound hypoglycemia, elderly or young patients, patients with a limited life expectancy, or patients who need surgery more urgently.
- Use details of the patient's current glycemic therapy to plan for perioperative glucose management.
- Discuss the risks and symptoms of hypoglycemia and cardiac ischemia when discussing other general perioperative risks with the patient before surgery.
- Encourage patients with diabetes to monitor their own glucose levels the night before and the morning of surgery, and to contact a physician if any low readings are found (<70 mg/dL or <4.0 mmol/L).
- Recommend that surgery be scheduled as early in the morning as possible to minimize disruption in glycemic control.

Evidence

- In a case-controlled study of patients with deep sternal site infections after CABG, those with diabetes with a preoperative glucose level >110 mg/dL had a higher risk for deep sternal wound infections (OR, 1.4 [CI, 0.4 to 4.8]; P=0.6) (7).
- A prospective cohort study of outpatients showed that low self-monitored blood glucose levels predicted severe episodes of hypoglycemia (stupor or unconsciousness) among patients with type 1 diabetes (21).
- The 2012 Standards of Medical Care in Diabetes from the American Diabetes Association suggest a goal HbA1c of around 7.0% in most patients with diabetes (41).

Rationale

- Because patients will likely have altered their meal times and be fasting before surgery, glucose should be monitored at home to ensure levels are not low; patients should be vigilant for early symptoms of hypoglycemia before and after surgery.
- Early identification of hypoglycemia allows for prompt treatment to halt progression.
- Diabetic patients are at increased risk of having CAD; these patients need to be able to identify symptoms of cardiac ischemia and to seek medical attention immediately.
- Determining details of outpatient therapy helps guide intraoperative diabetes management and allow for accurate resumption of the patient’s medication therapy in the postoperative phase.
- Early morning surgery, especially for procedures when the patient is expected to resume oral intake on the same day, minimizes disruption in glucose reduction therapy and may help maintain glycemic control.

3.2 Continue β-blockers perioperatively in diabetic patients who are already receiving them, but do not start β-blockers preoperatively.
Recommendations

- Continue β-blockers during the perioperative period in patients who are already receiving them.
- Consider starting β-blockers only in patients with a nonsurgical indication such as heart failure or CAD.

Evidence

- A 2008 systematic review of the effect of perioperative β-blockers on mortality included 33 trials with 12,306 patients, and found that treatment with β-blockers did not lead to improved all-cause or cardiovascular mortality. Treatment was associated with a decrease in nonfatal MI (NNT, 63) and an increase in nonfatal stroke (NNH, 293) (42; 43).
- The 2009 update of the 2007 ACCF/AHA guideline on perioperative cardiac evaluation recommends continuing β-blockers in patients who are already receiving them and considering β-blockers in patients at high risk for cardiac complications or those undergoing high-risk surgery (26).

Rationale

- β-blockers may have benefits as well as harms in the perioperative setting.
- Patients receiving β-blockers may be harmed by their abrupt withdrawal.

3.3 Consult with the anesthesiologist to reduce the risk for hypoglycemia and electrolyte abnormalities.

Recommendations

- Consult with the anesthesiologist to ensure that:
  - Glucose levels are monitored at least every hour
  - If using insulin during surgery, potassium levels are measured every 4 to 6 hours during surgery and more frequently if the patient has renal failure or is taking an ACE inhibitor or potassium-sparing diuretics
  - Glucose is measured in the recovery room immediately after surgery
  - Anion gap and serum bicarbonate levels are measured in patients undergoing procedures longer than 6 hours

Evidence

- Consensus.
- In an observational study of 596 critically ill patients, hypoglycemia occurred in 21%. Hypoglycemia was associated with mortality, respiratory failure, and hemodynamic instability. In addition to diabetes, chronic renal failure was associated with hypoglycemia (36).

Rationale

- As patients under anesthetic are unable to communicate, hypoglycemia may go undetected; therefore, glucose levels should be monitored frequently during surgery.
- Insulin shifts potassium into the intracellular compartment; therefore, potassium levels should also be monitored closely if patients are receiving intraoperative insulin, at least every 3 to 6 hours.

3.4 Withhold oral medication before surgery in patients with type 2 diabetes who use oral hypoglycemic agents alone for glycemic control.

Recommendations

- Hold metformin for 1 or more days before surgery.
- On the day before surgery, ask patients to continue their usual oral hypoglycemic agents other than metformin.
- On the morning of surgery, withhold oral antidiabetic agents.
• Plan to use dextrose-containing iv solutions in patients who have been on sulfonylureas.
• Never withhold basal insulin.
• See table Recommendations for Management of Diabetes Medications and Insulin Before Surgery or a Procedure Requireing Fasting.

Evidence
• A 2011 systematic review evaluated perioperative medication management in order to make recommendations for best practices, and made recommendations regarding specific agents. The authors recommend holding metformin for 48 hours before surgery, although the recommendation was based on little evidence (44).

Rationale
• On the day of surgery, patients will usually be missing or delaying breakfast; therefore, oral hypoglycemic agents should be temporarily discontinued to prevent hypoglycemia.

Comments
• Common practice is to hold biguanides for only 1 day before surgery or just on the morning of surgery.
• Generally, no preoperative drug interventions are needed for patients with type 2 diabetes treated with diet alone.
• Some patients in this group are suboptimally treated for their hyperglycemia and are not taking any insulin as outpatients; these patients may require insulin to control a significantly elevated glucose level.

3.5 In patients receiving insulin, adjust insulin dosage before the surgical procedure to avoid hypoglycemia.

Recommendations
• Withhold all oral hypoglycemic agents on the morning of surgery.
• Alter the dosage of insulin depending on the outpatient drug regimen:
  • In patients taking long-acting insulin (e.g., glargine or detemir), give their customary morning and/or evening dose; do not resume pre-meal bolus doses of short- or rapid-acting insulin until patients are eating
  • For patients taking intermediate-acting insulin or mixed intermediate-acting and short- or rapid-acting insulin, either:
    o Administer half of the typical morning dose, or
    o Calculate the patient's TDI:
      ▪ Split the TDI into two equal parts of basal insulin (glargine or detemir) and prandial insulin (rapid-acting insulin analogs), the latter of which will be withheld until the patient eats/receives nutrition, or
      ▪ Split the TDI into four equal parts of basal and prandial insulin given as regular insulin every 6 hours, with half of the regular insulin dose given as basal insulin and the other half withheld until the patient eats/receives nutrition; thus, the patient will be given one-eighth of the TDI for basal insulin every 6 hours until eating
  • For patients on continuous subcutaneous insulin pumps, discontinue and disconnect the pump, and administer iv insulin or a dose of subcutaneous long-acting insulin (glargine or detemir) that equals their 24-hour subcutaneous basal infusion dose through the pump; calculation of the 24-hour basal insulin dose is held in the pump itself and can be accessed by the patient
  • For patients in whom hypoglycemia is a concern while fasting on a typical basal insulin dose, test the home insulin dose 5 to 7 days before surgery by having the patient fast at home, checking fingerstick glucose frequently.
• Reduce the amount of insulin given if the patient experiences frequent episodes of hypoglycemia in outpatient management.
• Never withhold basal insulin therapy.
• See table How to Adjust Insulin While Fasting for a Procedure (Patient Information).
• See table Calculation of TDI.
• See table Acceptable Insulin Regimens for Different Inpatient Scenarios.
• See table Recommendations for Management of Diabetes Medications and Insulin Before Surgery or a Procedure Requiring Fasting.

Evidence
• Mainly consensus.
• Adrenaline, cortisol, growth hormone, and glucagon are all stimulated by surgery or anesthesia. These hormones, coupled with basal metabolic requirements, increase the need for insulin perioperatively even if the patient is fasting (45).

Rationale
• Perioperative management of patients on insulin is largely empiric and should be based on knowledge of the patient's basal glucose control, the known stress of surgery and anesthesia on that control, and the patient's specific insulin regimen.

3.6 Recognize that patients with type 2 diabetes who are treated with diet alone occasionally require drug intervention in the perioperative setting.

Recommendations
• Consider supplemental perioperative short- or rapid-acting insulin, regular or lispro, given subcutaneously every 4 hours on correction-dose insulin for blood glucose levels above target.
• If correction-dose insulin is used longer than 24 hours, start scheduled insulin.
• Recognize that the frequent use of correction-dose insulin without scheduled insulin, previously known as ‘sliding-scale insulin,’ is no longer the standard of care.
• Aim for intraoperative and postoperative glucose targets between 140 mg/dL and 180 mg/dL.
• Start iv saline infusions at 100 mL/h to 150 mL/h for preoperative and intraoperative hydration.
• Recognize that the use of iv insulin may be necessary to achieve tight glycemic control more safely and quickly than subcutaneous insulin.
• See table Calculation of Correction-dose or Supplemental Insulin Dose.
• See table Extra Insulin to Give.

Evidence
• In a randomized trial, 60 patients with well-controlled type 2 diabetes on noninsulin outpatient therapy were randomly assigned to either iv insulin infusion at 1.25 U/h, 10 U q2h, or saline infusion during major surgery. Blood glucose concentrations were similar among the three groups. There was a mild-to-moderate increase in ketone body production in the saline group, but this increase did not lead to any deleterious consequences (46).
• A study of tight glycemic control in surgical patients admitted to an ICU found that nearly all patients, regardless of history of diabetes, required intensive insulin therapy to maintain a blood glucose level <110 mg/dL. In this study, only 13% of patients had a diagnosis of diabetes (2).
• The American Association of Clinical Endocrinologists and the American Diabetes Association published a consensus statement on inpatient glycemic control (47).
Rationale

- One study suggests that patients who do not require insulin or oral hypoglycemic agents as a part of their outpatient regimen will generally not have significantly elevated glucose levels perioperatively.
- The stress of surgery and pharmacologic agents given perioperatively can cause hyperglycemia in patients with no known history of diabetes and in those with diabetes, regardless of previous control or treatment.

Comments

- In assessing glycemic response to calculated correction-dose insulin and making dose adjustments, it is important to do so in anticipation of, rather than in reaction to, glycemic needs, with the dosage determined by glycemic response to preceding dosage(s).

3.7 Administer subcutaneous correction-dose insulin or an iv insulin infusion during minor or short surgical procedures in patients with diabetes treated with insulin with or without oral hypoglycemic agents with target glucose between 140 mg/dL and 180 mg/dL.

Recommendations

- For minor surgery:
  - Administer supplemental short-acting regular, lispro, aspart, or glulisine insulin in a correction dose for elevated blood glucose levels
  - Hydrate with saline or dextrose-containing solutions at 100 mL/h to 150 mL/h
- For major surgery:
  - Start:
    - Scheduled basal insulin in all patients
    - Prandial insulin in all patients who eat, timed to the meal and what the patient eats
    - Nutritional insulin in all patients who receive enteral or parenteral nutrition
  - Administer iv insulin infusion
  - Hydrate with saline or dextrose-containing solutions at 100 mL/h to 150 mL/h
- Aim for glucose targets between 140 mg/dL and 180 mg/dL.
- Recognize that the use of iv insulin may be necessary to achieve tight glycemic control more safely and quickly than subcutaneous insulin.
- Continue scheduled basal insulin in all patients on insulin therapy. Never hold basal insulin therapy in patients with type 1 diabetes.
- If a correction-dose of insulin is needed, use subcutaneous correction-dose insulin or iv insulin infusion.
- Do not use correction-dose insulin (‘sliding-scale insulin’) alone without scheduled basal insulin.
- Use a dextrose-containing solution in patients on insulin infusions.
- See the Yale Insulin Infusion Protocol.
- See table Acceptable Insulin Regimens for Different Inpatient Scenarios.
- See table Calculation of Correction-dose or Supplemental Insulin Dose.
- See table Recommendations for Management of Diabetes Medications and Insulin Before Surgery or a Procedure Requiring Fasting.

Evidence
• Consensus.

• In a randomized trial, 20 patients were assigned to subcutaneous insulin or iv insulin (GIK infusion) during minor surgery under general anesthesia. The iv insulin group had significantly lower blood glucose levels compared to the subcutaneous insulin group during the infusion period ($P<0.05$) (48).

• A randomized trial of 30 patients with diabetes (some requiring and some not requiring insulin) compared iv insulin infusion with a GIK drip or subcutaneous injections of insulin for elective major surgery. There was no significant difference in glucose levels 24 hours before or 24 hours after surgery. During surgery, 67% of the patients in the insulin infusion group were in the target range of 90 mg/dL to 180 mg/dL, whereas only 40% of the subcutaneous injection group was in the target range (49).

**Rationale**

• Oral agents are contraindicated for many reasons in patients undergoing surgery who may or may not eat and who may or may not suffer complications that can make oral agents dangerous.

• Use of oral agents in patients who are not eating can cause hypoglycemia.

• Insulin is easier than oral agents to titrate rapidly and safely.

• For patients requiring insulin who are undergoing minor surgical procedures, continuous iv insulin infusions will probably result in better control of glucose levels compared with subcutaneous insulin; however, none of the evidence considers whether the somewhat better glucose control achieved with iv insulin for minor surgical procedures results in outcome improvements such as rate of infections, myocardial ischemia, or length of hospital stay.

• In the absence of such evidence, either subcutaneous or iv insulin infusions could be used.

**Comments**

• Correction doses of short- or rapid-acting insulin are determined by assessing responses to previous doses so that insulin can be given in anticipation of, rather than in reaction to, glycemic needs.

• Whether insulin infusion is used depends on the degree of hyperglycemia, the type of surgery planned, and the kind of iv fluid being used (dextrose, iv alimentation fluid), regardless of the preoperative regimen used for glycemic control.

• Patients undergoing cardiac surgery who are treated with iv insulin have a decreased rate of sternal wound infection (50).

• Studies of insulin strategies have not evaluated important clinical outcomes such as mortality and wound infections. The strategy of insulin administration needs to take into account practicality (i.e., whether there is ability to safely monitor glucose levels intraoperatively and on the hospital ward postoperatively), and the physician's own judgment regarding the particular individual. The specific recommendations presented here represent a practical and reasonable approach to management (48; 49; 51).

• In assessing glycemic response to calculated correction-dose insulin and making dose adjustments, it is important to do so in anticipation of, rather than in reaction to, glycemic needs.

• Whether insulin infusion is used depends on the degree of hyperglycemia and the kind of iv fluid being used (dextrose, iv alimentation fluid) regardless of the preoperative regimen used for glycemic control.

**3.8 Use iv insulin infusions in patients with type 1 or type 2 diabetes treated with insulin and undergoing major surgical procedures.**

**Recommendations**
• In patients with type 1 or type 2 diabetes treated with insulin who are undergoing complex major surgical procedures such as CABG, use continuous iv insulin infusion hourly titrated based on point-of-care glucose values and change.

• Measure blood glucose levels hourly and electrolyte levels every 4 to 6 hours.

• Give insulin in the morning before surgery as recommended in 3.5.

• Aim for glucose targets between 120 mg/dL and 180 mg/dL (6.7 mmol/L and 10.0 mmol/L).

Evidence

• A 2012 noninferiority randomized, controlled trial compared liberal (120 mg/dL to 180 mg/dL) with tight (90 mg/dL to 120 mg/dL) glucose goals in 189 patients with diabetes undergoing CABG. There were no differences in rates of infection between the groups, but the liberal group had fewer episodes of hypoglycemia (52).

• A 2011 randomized, controlled trial compared liberal (120 mg/dL to 180 mg/dL) with tight (90 mg/dL to 120 mg/dL) glucose goals (achieved with insulin infusion) in 82 patients undergoing CABG. There were no differences in the rates of major adverse events between the groups, but there were fewer episodes of hypoglycemia in the tight control group (NNH 1.6) (53).

• A 2009 consensus statement from the American Association of Clinical Endocrinologists and the American Diabetes Association recommends a goal glucose range of 140 mg/dL to 180 mg/dL (7.8 to 10.0 mmol/L) in critically ill patients, and a goal fasting glucose of <140 mg/dL (<7.8 mmol/L) in non-critically ill patients, with random blood glucose levels <180 mg/dL (<10.0 mmol/L). The guideline does not specifically address intraoperative and perioperative patients (47).

• In a prospective cohort study of 2402 diabetic patients undergoing CABG, 968 patients received treatment with correction-dose insulin for the first 2 postoperative days, and 1499 patients received continuous iv insulin infusion. There was a significant reduction in the incidence of deep sternal wound infections in the group that received the insulin infusion (0.8% vs. 2.0%) (50). In a subsequent study, the same team reported reduced mortality in diabetic patients undergoing CABG (54).

• In 737 patients undergoing cardiac surgery, intra- and postoperative use of an insulin infusion protocol designed to achieve blood glucose levels of <130 mg/dL more than 50% of the time was accompanied by a reduction in the rate of mediastinitis from 1.6% (before initiation of the protocol) to 0%. It is noteworthy that 57% of the patients meeting the 130 mg/dL threshold for insulin therapy did not have a perioperative diagnosis of diabetes (55).

• The favorable effect on wound infection of postoperative continuous insulin infusion has also been reported for 761 patients undergoing CABG, 37% of whom were diabetic. Target blood glucose was 120 mg/dL to 160 mg/dL. Before the use of the infusion protocol, the rate of wound infections was significantly higher in the diabetic patients than in the nondiabetic patients. The use of the protocol was associated with a reduction in the rate of wound infections in the diabetic patients to that observed in the nondiabetic group (56).

Rationale

• For patients requiring insulin who undergo complex major surgical procedures, insulin infusions tend to control blood glucose levels better than intermittent insulin therapy and likely reduce perioperative infections.

Comments

• Because of consistent evidence showing the effectiveness and safety of meticulous glycemic control in the intensive care setting, particularly in cases of cardiac surgery, and because of consensus among experts (57), use an insulin infusion protocol in such a setting whenever possible. One should consider its use even in patients without a pre-ICU diagnosis of diabetes when target glycemia has been exceeded.
• Note that potassium levels may need to be checked more frequently if the patient has renal failure or is taking an ACE inhibitor, angiotensin-receptor blocking agent, or potassium-sparing diuretics.

• There are several different types of iv insulin infusions, each with its own benefits and disadvantages.
  • There is no clearly superior choice in insulin infusions
  • There are multiple insulin infusion protocols, including the Yale Insulin Infusion Protocol and the Trence-Hirsch Example of an Intravenous Insulin Infusion
  • In assessing glycemic response to calculated correction-dose insulin and making dose adjustments, it is important to do so in anticipation of, rather than in reaction to, glycemic needs
  • Whether insulin infusion is used depends on the degree of hyperglycemia and the kind of iv fluid being used (dextrose, iv alimentation fluid) regardless of the preoperative regimen used for glycemic control
  • Additional published examples of insulin infusion protocols that have been used successfully appear in 58, 59, and 60.

3.9 Control postoperative glucose levels to reduce both cardiac and infectious complications

Recommendations
• Maintain postoperative glucose levels (pre-meal and fasting) in the range of 100 mg/dL to 180 mg/dL in patients undergoing surgical procedures that are not long or complex.
• Maintain postoperative glucose levels in the range of <140 mg/dL at pre-meal and fasting times in patients undergoing cardiac surgery who are not critically ill.
• Recognize that iv insulin can be the safest way to titrate insulin when trying to obtain intensive glucose targets.
• Consider more stringent targets in stable patients with previous tight glycemic control or those who are pregnant.
• Consider less stringent targets for terminally ill patients.
• Do not use oral diabetes medications for the treatment of inpatient hyperglycemia; insulin is preferred.

Evidence
• A 2012 guideline from the British Diabetes Society and the National Health Service recommends goal blood glucose of 6 mmol/L to 10 mmol/L (100 mg/dL to 180 mg/dL) in the perioperative period and states that a range of 4 mmol/L to 12 mmol/L (approximately 80 mg/dL to 200 mg/dL) is acceptable (61).
• A prospective observational cohort study of 411 patients undergoing CABG found that increasing glucose levels were associated with increased risk of infections (chest wounds, pneumonia, or UTI). The odds of having an infection was 1.78 times higher if the glucose was 253 mg/dL to 352 mg/dL (14 mmol/L to 20 mmol/L) compared to 121 mg/dL to 253 mg/dL (6.7 mmol/L to 14 mmol/L) (62).
• A 2010 systematic review evaluated the impact of intensive insulin therapy compared with standard therapy in surgical patients. The meta-analysis was limited by heterogeneity but found no mortality benefit with intensive therapy (RR, 0.85 [CI, 0.69 to 1.04]) (63).
• A randomized, controlled trial of hyperglycemic patients admitted postoperatively to a surgical ICU compared intensive insulin therapy to conventional insulin therapy. For 1548 patients, who mostly underwent elective cardiac surgery, the intensive insulin group (glucose, 80 mg/dL to 110 mg/dL or 4.4 mmol/L to 6.1 mmol/L) had a 4.6% mortality rate compared to the conventional insulin therapy group (glucose, 180 mg/dL to 200 mg/dL or 10 mmol/L to 11 mmol/L) who had an 8.0% mortality rate (RR, 42%). The rate of sepsis was also lower with the intensive controlled group compared with the conventional group (25% vs. 67%) (2).
• A small, prospective, randomized study compared the effect of meticulous glycemic control achieved by GIK infusion with standard therapy in 141 diabetic patients undergoing CABG. The GIK group had significantly less atrial fibrillation, shorter hospital stay, fewer wound infections, fewer episodes of recurrent ischemia, and increased survival over 2 years (64).

• The Normoglycemia Intensive Care Evaluation - Survival Using Glucose Algorithm Regulation (NICE-SUGAR) study examined the effect of intensive vs. conventional glucose control on mortality and morbidity in critically ill patients, the majority of whom were on mechanical ventilation. Mortality, cardiovascular events, and hypoglycemia were higher in patients treated with intensive insulin. The conventional arm aimed to keep blood glucose ≤180 mg/dL, and the intensive arm aimed for glucose control between 80 mg/dL and 110 mg/dL (65).

Rationale
• Studies have suggested that significant hyperglycemia is associated with increased postoperative infections.

• Patients undergoing cardiothoracic surgery appear to benefit from moderate glucose targets.

Comments
• Appropriate target blood glucose in surgical patients remains controversial.

3.10 Continue intraoperative management strategies into the postoperative period if the patient remains unable to eat normally.

Recommendations
• If the patient is fasting without caloric intake, continue to provide basal insulin with correction-dose insulin if necessary.

• For patients undergoing more complex procedures on iv insulin infusions, continue infusion until the patient is able to eat.

• Upon resumption of caloric intake, provide the three components of insulin requirements in the hospital:
  • Basal insulin:
    o Continue iv insulin (with subcutaneous prandial insulin when eating)
    o Note the subcutaneous insulins used for basal insulin:
      ▪ Glargine every 12 to 24 hours
      ▪ Detemir every 12 hours
      ▪ Regular every 6 hours
      ▪ NPH twice a day
    o Dose subcutaneous basal insulin by extrapolating 24-hour insulin use from the past 12 hours of iv insulin use
  • Prandial or nutritional insulin:
    o Administer:
      ▪ Rapid-acting insulin analogs (lispro, aspart, glulisine) before or after a meal, dosed according to how much the patient eats, or
      ▪ Short-acting regular insulin with meals, dosed by doubling the regular insulin dose used for basal insulin
    o Dose prandial insulin by the rule of 500 or by dividing the dose of insulin used for basal insulin by 3 (over 3 meals)
  • Correction-dose insulin:
    o Match correction-dose insulin to the type of insulin used to cover prandial needs
    o Dose correction-dose insulin by using the 5% rule or the rule of 1600
• Check the dose by calculating the TDI:
• 0.3 U/kg.d in patients with type 1 diabetes
• 0.5 to 1.0 U/kg.d in patients with type 2 diabetes

Do not stop iv insulin until basal insulin has been given for 1 to 3 hours (depending on the type of basal insulin given).

• Check fingerstick glucose every hour for 3 hours after the first subcutaneous basal insulin injection has been given; do not wean off of iv insulin until the blood glucose level is <150 mg/dL, which will prevent hyperglycemia if an inadequate amount of basal insulin was given.

• See table Calculation of Correction Dose or Supplemental Insulin Dose.

• See table Calculation of Prandial Insulin Dose.

Evidence

• In a prospective cohort study of 2402 patients undergoing CABG, 968 patients received treatment with correction-dose insulin for the first 2 postoperative days and 1499 patients received continuous iv insulin infusion. There was a significant reduction in the incidence of deep sternal wound infections in the group that received the insulin infusion (0.8% vs. 2.0%) (50).

• In a randomized trial of patients experiencing hyperglycemia, patients with stress-induced hyperglycemia were successfully transitioned to detemir insulin at a dose of 50% of the previous 24-hour iv insulin requirements, in addition to using aspart insulin with a dose based on carbohydrate intake. Patients with diabetes required a dose that was a higher percentage of the previous 24-hour insulin requirements (66).

• The transition-to-target study did not find a significant difference in glucose control using a weight-based regimen or transitioning at 60% or 80% of the previous 24-hour insulin use (67). If patient is clinically stable and fasting, the Duke University Health System Diabetes Management Service uses 100% of the TDI (68).

Rationale

• Patients may not be able to eat after surgery for a variety of reasons, such as nausea from anesthesia or drug side effects, or development of ileus.

• It is important in the postoperative phase to maintain glucose in the target ranges (depending on the surgery type) to minimize both hyper- and hypoglycemia and to decrease morbidity and mortality.

• The approach to achieve these goals has to be tailored to the patient's level of insulin resistance.

Comments

• In assessing glycemic response to calculated correction-dose insulin and making dose adjustments, it is important to do so in anticipation of, rather than in reaction to, glycemic needs.

• Whether insulin infusion is used depends on the degree of hyperglycemia and the kind of iv fluid being used (dextrose, iv alimentation fluid) regardless of the preoperative regimen used for glycemic control.

• Other regimens exist for the transitional period that begins when the patient resumes eating. One such regimen calculates the expected 24-hour insulin requirement from the amount of insulin infused during the last 6 to 8 hours. Eighty percent of this calculated 24-hour requirement is taken as the new TDI; 50% of this amount is given as intermediate-acting insulin twice daily or once daily as insulin glargine; the remaining 50% is given as prandial rapid-acting insulin analogs (lispro, aspart, glulisine) (69).

3.11 Resume the patient's outpatient diabetic diet and treatment regimen once he or she is eating well.cá

Recommendations
• Consult with the surgical team to ensure that patients with diabetes are given appropriate diabetic diets (i.e., no concentrated sweets, controlled or fixed carbohydrate diet) when oral intake is resumed.

• Guided by the patient's preoperative regimen, resume oral hypoglycemic agents only once the patient is eating normally and has no contraindications to oral or other diabetes therapy.

• Do not restart metformin if there is renal insufficiency with creatinine clearance <60 mL/min, hypoxia, hypotension, significant hepatic impairment, COPD, or HF.

• Be aware that sulfonylureas, meglitinides, and exenatide stimulate insulin secretion and may, therefore, cause hypoglycemia; use these agents only when eating has been well established.

• Consider a step-up approach for those on high-dose sulfonylureas, administering doses at increasing increments until the patient's usual dose is reached.

• Recognize that exenatide and pramlintide cause significant nausea, and may not be appropriate for or tolerated by patients recovering from surgery.

• Be aware that metformin causes significant nausea, diarrhea, and abdominal bloating, and may not be appropriate for or tolerated by patients recovering from surgery.

• Minimize the length of time spent on correction-dose insulin if the patient is able to eat.

• Review glucose levels and insulin doses every 12 to 24 hours, and if correction-dose insulin is used frequently, increase the scheduled basal and prandial insulin doses to reflect and anticipate increased insulin needs.

• If the patient did not have good glycemic control preoperatively or has had a complication that would preclude using an outpatient regimen, discharge the patient on the inpatient regimen or a modification of the outpatient regimen.

• Initiate basal insulin in patients with HbA₁c levels >8% who have contraindications to outpatient oral medications.

• Initiate basal and prandial insulin in patients with HbA₁c levels >10% or contraindications to outpatient oral medications.

Evidence

• Mainly consensus.

• In a prospective study of 47 patients with DKA, correction-dose insulin was associated with higher median glucose values (262 mg/dL vs. 200 mg/dL) and longer length of hospital stay (6.3 vs. 4.4 days) compared to restarting outpatient drug therapy (70).

• In 171 patients with diabetes admitted to a medical unit, predictors of hyperglycemia included use of correction dose alone (RR, 2.85; P<0.05) (71).

Rationale

• Diets designed for patients with diabetes minimize postoperative hyperglycemia.

• Correction-dose insulin regimens are practical for patients who are not eating for short durations; however, once the patient begins eating, reintroducing outpatient hypoglycemic medications reduces fluctuations in glucose and reduces length of hospital stay.
4. Patient Counseling Top

Provide patients with information about their surgery, the importance of perioperative glucose control, and symptoms of hypoglycemia.

4.1 Discuss with patients the planned glycemic management strategy and how to recognize hypoglycemia.

Recommendations

- Inform patients of the warning symptoms and signs of hypoglycemia and strategies to avoid and relieve them.
- Instruct patients to regularly monitor their glucose levels when diet alterations are made before surgery.
- Instruct patients to continue their usual diabetic diets and to follow the surgeon's advice regarding when to stop eating.
- Instruct patients to alter their outpatient drug therapy before surgery (see information on preoperative drug intervention).
- Consider referring patients with poor control of their diabetes or those who are newly diagnosed with diabetes to patient education centers before or after the planned surgery.
- Arrange for inpatient diabetes self-management education before discharge from the hospital for patients new to insulin therapy (initiated during the hospitalization).

Evidence

- In a prospective cohort study of 280 patients with diabetes, those who received automated self-care assessment calls with nursing phone call follow-up had fewer symptoms of hypo- or hyperglycemia ($P<0.001$) (72).
- In a case-controlled study of 21 patients who had severe hypoglycemia, patients were found to have less knowledge about diabetes than those who did not experience severe hypoglycemia. The investigators concluded that patients' lack of knowledge about the symptoms and signs of hypoglycemia is strongly associated with development of hypoglycemia (72).
- A randomized, controlled trial of patients with HbA1c levels $>8.5\%$ were randomly assigned to receive an intensive education program with structured curriculum or educational material. HbA1c levels fell equally in both groups ($-2.0\%$) at 12 months ($P<0.001$) (74).
- In a randomized, controlled trial of 170 patients with type 2 diabetes, patients were randomly assigned to either individual or group educational settings. Both groups in the study had similar improvements in knowledge, BMI, health-related quality of life and reduction in HbA1c compared to baseline. HbA1c level at baseline fell from $8.5\% \pm 1.8\%$ to $6.5 \pm 0.8\%$ at 6 months (75).
- A technical review discusses the importance of diabetes self-management education for the hospitalized patient (57).

Rationale

- Because patients will not be eating, hypoglycemia may develop; educating patients on early symptoms may prevent serious neuroglycopenia.
- Patients who understand what their management plan will be and how to avoid serious complications may be better prepared for surgery.
The preoperative medical assessment provides patients with an opportunity to have their diabetes management reviewed and an attempt to improve glycemic control.

Comments
- Patient education and perioperative management may be facilitated by a team approach, including teaching competent adult patients about elements of self-management while hospitalized.

4.2 Use the perioperative setting to review strategies to prevent complications of diabetes.

Recommendations
- Use the perioperative setting to:
  - Review cardiac risk factors and appropriate risk reduction management, such as:
    - Smoking cessation
    - Lipid and BP control
    - Regular physical activity
  - Review diabetes glucose goals, including:
    - Fasting glucose goals
    - Postprandial glucose goals
    - HbA1c
    - How to recognize and treat hypoglycemia
  - Review diabetic complications and appropriate management, such as screening according to accepted recommendations for:
    - Diabetic nephropathy
    - Peripheral neuropathy
    - Foot care
    - Infections
    - Retinopathy
- See module Diabetes Mellitus, Type 1.
- See module Diabetes Mellitus, Type 2.
- See module Coronary Heart Disease.

Evidence
- In the Steno-2 study, 160 patients were randomly assigned to usual care vs. intensive, targeted, multifactorial intervention on modifiable risk factors for cardiovascular disease in patients with type 2 diabetes and microalbuminuria. Intensive risk factor reduction targeted glycemic control, BP control, dyslipidemia, microalbuminuria, and secondary prevention of cardiovascular disease with aspirin. Patients assigned to intensive therapy had a significantly lower risk of cardiovascular disease (hazard ratio, 0.42) (76).
- A post-test survey showed that simple postdischarge educational classes improved knowledge of CAD and health-promoting behaviors (77).
- Studies on the prevention of foot ulceration using education in diabetes suggest that there may be a short-term benefit to education (78).

Rationale
- The postoperative assessment provides an opportunity for the physician to provide risk-factor reduction management to prevent progression of cardiac and diabetic complications.

Comments
• The American Diabetes Association recommends statin therapy to achieve an LDL cholesterol target <100 mg/dL and a BP target <130/80 mm Hg, ACE inhibitor or angiotensin-receptor blocker therapy to achieve a BP target <130/80 mm Hg and reduce microalbuminuria, and aspirin therapy if there are no contraindications. The ADA also recommends yearly dilated eye exam and nightly foot exam.

• Starting medications that are considered the standard of care in patients with diabetes prevents vascular complications.
5. Follow-up

Evaluate patients daily after surgery for glycemic control and prevention of complications.

5.1 Monitor patients closely after surgery to optimize glycemic management.

**Recommendations**

- Monitor glucose levels frequently:
  - In patients who are eating, monitor glucose levels up to five times per day (pre-meal for breakfast, lunch, and dinner as well as bedtime)
  - In patients who are not eating but are receiving continuous (24 h/d) parenteral or enteral nutrition, monitor glucose every 4 to 6 hours
  - Check glucose at 3 AM if a change in basal insulin has been made or the patient has had hypoglycemia in the past 24 hours
  - Consider testing patients with type 1 diabetes even more frequently
- Adjust basal and prandial insulin at least daily, and review the total amount of correction-dose insulin used in the past 12 to 24 hours and add it to the scheduled insulin dose.
- Administer insulin according to scheduled basal and prandial/nutritional needs, and give correction-dose insulin if the blood glucose level is higher than the goal.
- Do not withhold basal insulin.
- Avoid the frequent use of correction-dose insulin alone (‘sliding-scale insulin’) without scheduled basal insulin.
- Measure other electrolytes, such as potassium, as needed:
  - For patients on insulin infusions, measure potassium levels every 6 hours
  - Note that potassium levels may need to be checked more or less frequently depending on renal function and concomitant drug use, such as with ACE inhibitors, angiotensin-receptor blocking agents, potassium-sparing diuretics, or other diuretics
- Measure bicarbonate levels, ketones, and anion gap every other day or as needed for patients who are insulin-deficient to monitor for DKA.
- Aim to keep glucose levels within the target ranges and avoid hypoglycemia and marked hyperglycemia.
- Recognize factors that increase the risk of inpatient hypoglycemia:
  - Change in caloric intake
  - Taper in glucocorticoid dose
  - Failure to adjust insulin dose daily based on glucose trends
  - Use of ‘sliding-scale insulin’ alone for longer than 24 hours
  - Administration of meals and insulin dose at separate times
  - Use of sulfonylurea therapy in patients with renal or liver failure
  - Not adjusting therapy if there is renal or liver failure
- If postoperative hyperglycemia is difficult to control, consider diet, dextrose-containing solutions, infection, or DKA as the cause of hyperglycemia.
- Follow dietary intake at least daily to guide reintroduction of outpatient medications.
- Reintroduce outpatient drug therapy as outlined in Postoperative Drug Intervention.
See table Acceptable Insulin Regimens for Different Inpatient Scenarios.

**Evidence**

- The American Association of Clinical Endocrinologists and the American Diabetes Association published a consensus statement on inpatient glycemic control (47).
- In an observational study of 596 critically ill patients, hypoglycemia occurred in 21%. Hypoglycemia was associated with mortality, respiratory failure, and hemodynamic instability. In addition to diabetes, chronic renal failure was associated with hypoglycemia (36).
- Achieving moderate-intensity glycemic control (target 110 mg/dL to 150 mg/dL) with iv insulin followed by multiple daily injections of scheduled and prandial insulin compared to standard-intensity glycemic control was associated with similar rates of hypoglycemia and decreased incidence of infection and atrial fibrillation after cardiac surgery (79).

**Rationale**

- With careful follow-up, glucose levels can be better controlled and hypoglycemia and marked hyperglycemia can be minimized.

### 5.2 Evaluate patients for postoperative cardiac and infectious complications.

**Recommendations**

- Use elements of the history, physical exam, and further testing as needed to assess for postoperative MI, wound infection, or other infections.
- Recognize that hyperglycemia may be a sign of infection.

**Evidence**

- Consensus.

**Rationale**

- Because postoperative MI often occurs 2 days to 4 days postoperatively and may have atypical symptoms, patients will need to be monitored for cardiac complications.
- Patients with diabetes may also develop postoperative wound infections or other infections.
References


Glossary

**ACC/AHA**
American College of Cardiology/American Heart Association

**ACE**
angiotensin-converting enzyme

**bid**
twice daily

**BMI**
body mass index

**BP**
blood pressure

**BUN**
blood urea nitrogen

**CAD**
coronary artery disease

**CDC**
Centers for Disease Control and Prevention

**CI**
confidence interval

**COPD**
chronic obstructive pulmonary disease

**DKA**
diabetic ketoacidosis

**ECG**
electrocardiography

**HbA1c**
glycosylated hemoglobin

**HF**
heart failure

**GIK**
glucose-insulin-potassium

**ICU**
intensive care unit

**iv**
intravenous

**LDL**
low-density lipoprotein

**MI**
myocardial infarction

**NPH**
neutral protamine Hagedorn

**OR**
odds ratio

**RR**
risk ratio
sc
subcutaneous

TDI
total daily insulin dose

UTI
urinary tract infection
### Tables

#### Recommendations for Management of Diabetes Medications and Insulin Before Surgery or a Procedure Requiring Fasting

<table>
<thead>
<tr>
<th>Medication</th>
<th>Night Before Surgery</th>
<th>Morning Before Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfonylureas:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glyburide; Glipizide; Glimepiride</td>
<td>Give (usually given with meals)</td>
<td>Hold</td>
</tr>
<tr>
<td>Metformin (contraindicated in men with creatinine levels ≥1.5 mg/dL and women with creatinine levels ≥1.4 mg/dL)</td>
<td>Hold</td>
<td>Hold</td>
</tr>
<tr>
<td>Thiazolidinediones:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rosiglitazone; Pioglitazone</td>
<td>May give; contraindicated in patients with class III-IV heart failure</td>
<td>May give; very long acting; can cause fluid retention</td>
</tr>
<tr>
<td>Meglitinide:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repaglinide; Nateglinide</td>
<td>Give with meals</td>
<td>Hold</td>
</tr>
<tr>
<td>α-Glucosidase inhibitors:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acarbose; Miglitol</td>
<td>Give with meals</td>
<td>Hold</td>
</tr>
<tr>
<td>Dipeptidase-IV inhibitor:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitagliptin</td>
<td>Give with meals</td>
<td>Hold</td>
</tr>
<tr>
<td>Incretin mimetics:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exenatide</td>
<td>Give 30-60 min before meals</td>
<td>Hold</td>
</tr>
<tr>
<td>Amylin analog:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exenatide</td>
<td>Give immediately before meals</td>
<td>Hold</td>
</tr>
<tr>
<td>Regular insulin:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humulin® R Novolin® R ReliOn R</td>
<td>Give full dose</td>
<td>Give half dose</td>
</tr>
<tr>
<td>NPH insulin:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humulin® N Novolin® N ReliOn N</td>
<td>Give full dose</td>
<td>Give half dose</td>
</tr>
<tr>
<td>Premixed insulins:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humulin® 70/30 Novolin® 70/30 Humalog® 75/25 Novolog® 70/30</td>
<td>Give full dose</td>
<td>Give half dose</td>
</tr>
<tr>
<td>Rapid-acting insulin:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspart; Glulisine; Lispro; Inhaled insulin</td>
<td>Give full dose with meals</td>
<td>Hold</td>
</tr>
</tbody>
</table>
### Basal insulin (long acting):
- Glargine; Detemir

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>If patient is on basal insulin and rapid-acting insulin, give full dose.</td>
<td>If patient is on oral diabetes medications plus basal insulin or basal insulin only, give half dose</td>
</tr>
<tr>
<td>If patient is on oral diabetes medications plus basal insulin or basal insulin only, give half dose</td>
<td>If patient is on oral diabetes medications plus basal insulin or basal insulin only, give half dose</td>
</tr>
</tbody>
</table>

### Continuous subcutaneous insulin infusion (insulin pump)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Action</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continue current settings</td>
<td>Contact patient's diabetes provider for recommendations</td>
<td></td>
</tr>
</tbody>
</table>

Nothing replaces understanding the action of the different types of insulin and diabetes management in making appropriate clinical decisions about perioperative blood glucose control.

NPH = neutral protamine Hagedorn.
How to Adjust Insulin While Fasting for a Procedure (Patient Information)

<table>
<thead>
<tr>
<th>Insulin pump or insulin glargine</th>
</tr>
</thead>
<tbody>
<tr>
<td>If you are on an insulin pump or take insulin glargine as your basal insulin, fasting for a procedure should be relatively easy, and you should not have to make changes in your insulin regimen unless your basal insulin rates or dose is incorrect. If your basal insulin rates or insulin glargine dose is correct, take your normal amount of insulin glargine or continue your normal basal rates, but do not bolus with extra insulin lispro or insulin aspart.</td>
</tr>
<tr>
<td>If you feel that it is unsafe for you to continue the same insulin glargine dose or basal insulin dose, then your basal insulin (either via pump or with insulin glargine) may be incorrect, and you should do a fasting test a few weeks before the procedure.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other insulin regimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>If you are a big eater, this may indicate that most of the insulin you take is for the food you eat. If this is the case, you may want to consider taking just a quarter of your regular or 70/30 dose when fasting.</td>
</tr>
</tbody>
</table>

Other insulin regimens

| If you are undergoing preparation for colonoscopy, you may want to see the recommendations above for those on insulin glargine or an insulin pump. If you do not know how to count carbohydrates, then eat sugar-free gelatine and drink mostly chicken broth and sugar-free, clear soda. If your blood glucose drops below 100 mg/dL, you can drink 4 oz of soda with sugar in it (clear ginger ale or lemon-lime soda). |

When you arrive at the test site, make sure that the nurses know you have diabetes, and ask them to monitor your blood glucose throughout the procedure. If your blood glucose is < 100 mg/dL, you should receive intravenous saline with a little bit of glucose (DS). Ask your driver to hold onto your glucometer in case the nurses at the test site do not check your fingerstick as frequently as you would like.

**Oral medications**

| If you are undergoing preparation for colonoscopy, you should consume mainly sugar-free soda and gelatin during the day. Chicken broth has some calories, and you can drink that over something sweet. If your blood glucose drops below 100 mg/dL, you can drink 4 oz of soda with sugar in it (clear ginger ale or lemon-lime soda). |

NPH = neutral protamine Hagedorn.
### Calculation of TDI

<table>
<thead>
<tr>
<th>Weight</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1 diabetes</td>
<td>0.3-0.5 U/kg</td>
<td></td>
</tr>
<tr>
<td>Type 2 diabetes</td>
<td>0.5-0.1 U/kg</td>
<td></td>
</tr>
</tbody>
</table>

**Compare to:**

- Previous home regimen
  - If the home regimen insulin dose does not match what the above calculations indicate, consider the following:
    - Inquire if the patient ever skips insulin
    - Consider if the patient may have more insulin resistance
    - Consider if the patient may be eating a lot of calories and more than half of the home regimen insulin covers prandial needs

- Previous insulin needs
  - Review the total amount of correction dose insulin used in the past 12-24 h and add it to the scheduled insulin dose

TDI = total daily insulin dose.
# Acceptable Insulin Regimens for Different Inpatient Scenarios

<table>
<thead>
<tr>
<th>Clinical Setting</th>
<th>Basal Insulin</th>
<th>Prandial/Nutritional Insulin</th>
<th>Correction Dose Insulin</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eating meals</td>
<td>NPH bid</td>
<td>Rapid-acting analog</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 1 diabetes</td>
<td>NPH at bedtime</td>
<td>Regular</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Glargine every 24 h</td>
<td>Rapid-acting analog</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Levemir every 12 h</td>
<td>Rapid-acting analog</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>iv</td>
<td>Rapid-acting analog sc</td>
<td>iv</td>
<td></td>
</tr>
<tr>
<td>Eating meals</td>
<td>NPH at bedtime</td>
<td>Rapid-acting analog or regular</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 2 diabetes</td>
<td>Glargine every 24 h</td>
<td>Rapid-acting analog</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Levemir every 12-24 h</td>
<td>Rapid-acting analog</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>iv</td>
<td>Rapid-acting analog sc</td>
<td>iv</td>
<td></td>
</tr>
<tr>
<td>Not eating</td>
<td>Regular every 6 h</td>
<td>Do not give prandial insulin if the patient is not eating or receiving nutrition</td>
<td>Regular every 6 h</td>
<td></td>
</tr>
<tr>
<td>Type 1 diabetes</td>
<td>Glargine every 24 h</td>
<td>Rapid-acting analog</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Levemir every 12 h</td>
<td>Rapid-acting analog</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>iv</td>
<td>Rapid-acting analog sc</td>
<td>iv</td>
<td></td>
</tr>
<tr>
<td>Not eating</td>
<td>Regular every 6 h</td>
<td>Do not give prandial insulin if the patient is not eating or receiving nutrition</td>
<td>Regular every 6 h</td>
<td></td>
</tr>
<tr>
<td>Type 2 diabetes</td>
<td>Glargine every 24 h</td>
<td>Rapid-acting analog</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Levemir every 12-24 h</td>
<td>Rapid-acting analog</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>iv</td>
<td>Rapid-acting analog sc</td>
<td>iv</td>
<td></td>
</tr>
<tr>
<td>ICU</td>
<td>iv unless tight glycemic control already achieved by the above methods</td>
<td>Convert to sc once the patient is eating or cover oral nutrition with sc rapid analogs as above</td>
<td>iv</td>
<td>Administration of regular insulin every 6 h is preferred to cover caloric transitional formula. If feeds are stopped, the patient will need much less than half for basal insulin</td>
</tr>
<tr>
<td>Enteral feeds, continuous</td>
<td>Regular every 6 h</td>
<td>Regular every 6 h</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Glargine every 24 h</td>
<td>Rapid-acting analog every 4 h</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Levemir every 12 h</td>
<td>Rapid-acting analog every 4 h</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Perioperative Management of Diabetes Mellitus

| Enteral feeds, bolus       | Regular every 6 h | Regular every 6 h | Administer regular insulin every 6 h for enteral feed boluses every 3 h or a rapid-acting insulin analog for enteral feed boluses every 4 h |
|----------------------------|-------------------|-------------------|---------------------------------------------------------------------------------------------------------------------------------
|                            | Glargine every 24 h| Rapid-acting analog every 4 h |                                                                                                                                 |
|                            | Levemir every 12 h |                   |                                                                                                                                 |

bid = twice daily; ICU = intensive care unit; iv = intravenous; NPH = neutral protamine Hagedorn; sc = subcutaneous.
Calculation of Correction Dose or Supplemental Insulin Dose

Rule of 1600

Divide 1600 by the TDI to find the correction factor, the number by which the blood glucose level will decrease with 1 U of insulin. For instance, if the patient is taking 50 U of insulin, 1600 divided by 50 is 32. Write the correction scale based on the formula \((\text{blood glucose level} - 150)/30\).

5% Rule

If the hospital protocol only allows correction scales based on 50, use the 5% rule to dose the correction scale. Take 5% of the TDI, which is the number to use between dose 201 and 250.

TDI = total daily insulin dose.
### Extra Insulin to Give

<table>
<thead>
<tr>
<th>Glucose Level (mg/dL)</th>
<th>TDI 20</th>
<th>TDI 40</th>
<th>TDI 60</th>
<th>TDI x</th>
</tr>
</thead>
<tbody>
<tr>
<td>150-200</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0.5 x</td>
</tr>
<tr>
<td>201-250</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1 x</td>
</tr>
<tr>
<td>251-300</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>2 x</td>
</tr>
<tr>
<td>301-350</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>3 x</td>
</tr>
<tr>
<td>351-400</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>4 x</td>
</tr>
<tr>
<td>&gt;400</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>5 x</td>
</tr>
</tbody>
</table>

TDI = total daily insulin dose.
## Calculation of Prandial Insulin Dose

<table>
<thead>
<tr>
<th>Rule of 500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divide 500 by the TDI to obtain the insulin-to-carbohydrate ratio. For instance, if the patient’s TDI is 40 U, 500 divided by 40 is 12.5; give 1 U per 12 g of total carbohydrate</td>
</tr>
</tbody>
</table>

### Total prandial insulin should generally equal total basal insulin

If the staff is unable to count carbohydrates, approximate total prandial insulin needs by making it the same amount as total basal insulin needs. Thus, if the patient is taking 20 U of basal insulin daily, divide 20 by 3; give 6-7 U of prandial insulin per meal

### Transitioning from iv insulin to sc insulin

If the patient had not been eating while on iv insulin and is not going to eat:

- Add up the total amount of iv insulin used over the past 12 h and extrapolate the 24-h dose
- Give that dose as glargine every 24 h or levmir every 12 h

Before shutting off the drip, check fingerstick glucose every hour for 3 h

If the blood glucose level increases or the patient remains on a significant amount of iv insulin, do not stop the iv infusion, but recalculate the sc dose to account for higher insulin needs

Glargine and levmir can be given every 12 h as necessary to wean patients off of iv insulin

If the patient has not been eating while on iv insulin but is about to eat, recognize that the iv insulin requirements were covering only basal insulin needs

Calculate basal insulin as above

Dose prandial insulin by reviewing the calculation of prandial infusion shown above

It is helpful to give prandial insulin immediately after a meal once it has been determined how many carbohydrates have been ingested or tolerated in an ill patient postoperatively

iv = intravenous; sc = subcutaneous; TDI = total daily insulin dose.
### Figures

#### HbA1c Guidance

HbA1c = glycosylated hemoglobin.

Reprinted from [80].

<table>
<thead>
<tr>
<th>HbA1c</th>
<th>Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>HbA1c &lt;8% or 10% or fasting glucose &gt; 250 mg/dL</td>
<td>Multiple daily injections with carbohydrate intake adjustment</td>
</tr>
<tr>
<td>HbA1c 8-9%</td>
<td>Intensify insulin</td>
</tr>
<tr>
<td>HbA1c 7-8%</td>
<td>Add basal insulin</td>
</tr>
<tr>
<td>HbA1c &lt;7% and no new contraindication to prior outpatient therapy, resume home medication at discharge</td>
<td></td>
</tr>
</tbody>
</table>

---

---