Special Topic

Perioperative Glycemic Control in Plastic Surgery: Review and Discussion of an Institutional Protocol

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Abstract

Perioperative hyperglycemia is a well-known risk factor for surgical morbidity such as wound healing, infection, and prolonged hospitalization. This association has been reported for a number of surgical subspecialties, including plastic surgery. Specialty-specific guidelines have become increasingly available in the literature. Currently, glucose management guidelines for plastic surgery are lacking. Recognizing that multiple approaches exist for perioperative glucose, protocol-based models provide the necessary structure and guidance for approaching glycemic control. In this article, we review the influence of diabetes on outcomes in plastic surgery patients and propose a practical approach to perioperative blood glucose management based on current Endocrine Society and Mayo Clinic institutional guidelines.

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According to the Centers for Disease Control and Prevention, 29.1 million Americans have diabetes, representing 9% of the United States population. Diabetes is the seventh leading cause of death in the United States and the fourth most prevalent comorbid condition among patients admitted to the hospital. For decades, healthcare providers have recognized that hyperglycemia is associated with an increased risk of wound infection. Hyperglycemia has also been associated with increased mortality, longer hospital stay, and significant disability following discharge. Clearly, the risk of postoperative complications correlates directly with the degree of perioperative hyperglycemia. The growing body of literature documenting the benefits of careful perioperative glycemic control has led to the inclusion of postoperative blood glucose as a core measure set forth by The Joint Commission for patients undergoing specific procedures, such as cardiac surgery. The Surgical Care Improvement Project developed by the Centers for Medicare and Medicaid Services has added perioperative glucose control as a quality measure. With the changing face of healthcare reimbursement and introduction of pay for performance models, a proactive approach to identifying and controlling perioperative hyperglycemia is essential to improve quality of care and overall surgical outcomes.

Recently, specialty-specific guidelines for perioperative management of hyperglycemia have become increasingly available. It is imperative that plastic surgeons have a well-developed process which: (1) screens operative candidates for inadequate glycemic control; (2) improves preoperative control of patients with borderline control; and (3) achieves adequate glycemic control throughout the postoperative phase. These goals should be standardized for surgical patients in the inpatient setting, as well as patients in the ambulatory setting who are susceptible to glucose derangements and may be subject to less stringent perioperative monitoring. Recognizing that multiple approaches exist for perioperative glucose management, protocol-based models provide the necessary structure and guidance for approaching glycemic control. In this article, we review the influence...
of diabetes on outcomes in plastic surgery patients and propose a practical approach to perioperative blood glucose management based on current Endocrine Society and Mayo Clinic institutional guidelines.

**PATHOPHYSIOLOGY OF PERIOPERATIVE HYPERGLYCEMIA**

Hyperglycemia is a physiologic response to surgical stress which is compounded in the setting of diabetes. Surgical trauma activates the hypothalamic-pituitary-adrenal axis, resulting in elevated cortisol and catecholamine levels. These hormones synergistically lead to reduced insulin sensitivity and secretion. The subsequent sympathetic response to surgery results in increased growth hormone and glucagon secretion leading to gluconeogenesis, glycogenolysis, and subsequent hyperglycemia. Extrinsic factors during the administration of anesthesia and stabilization phase after surgery are also implicated in elevated perioperative blood glucose levels. Specific anesthetic agents such as etomidate, isoflurane, or midazolam may contribute to perioperative hyperglycemia through either increased glucose production or impaired clearance. Corticosteroid administration, parenteral nutrition and various IV formulations diluted in 5% dextrose are other iatrogenic treatments that potentially complicate glucose homeostasis. In the non-diabetic patient, such physiologic changes are often well tolerated. However, among patients with impaired glucose homeostasis at baseline, the resulting hyperglycemia can be detrimental.

Wound healing and immunologic defense mechanisms are impaired in the setting of hyperglycemia secondary to a variety of factors including decreased vasodilation, impaired endothelial nitric oxide production, decreased complement function, increased cytokine levels, and impaired neutrophil chemotaxis and phagocytosis. In combination, these alterations in the diabetic surgical patient lead to significant wound related complications as well as other manifestations of end organ dysfunction such as renal, pulmonary and cardiovascular complications.

**DIABETES IMPACT ON PLASTIC SURGERY OUTCOMES**

**Breast Reconstruction**

In the United States, the popularity of post-mastectomy reconstruction has increased dramatically in recent years. This increased volume of reconstructive procedures has led to greater focus on surgical outcomes with complication rates ranging from roughly 30% to 50%. Although established risk factors such as obesity, smoking and radiation contribute to poor wound healing, diabetes carries a significant association with wound complications following reconstructive breast surgery. One of the most challenging issues facing the plastic surgeon is mastectomy skin flap necrosis, which occurs in 2% to 22% of patients. A recent study of patients undergoing nipple-sparing mastectomy with implant-based reconstruction showed a 20.4% incidence of nipple-areolar complex (NAC) ischemia. In this study, diabetes had a statistically significant association with NAC ischemia. Another prospective report of patients at a single institution demonstrated a flap necrosis rate of 14% and noted that diabetes was associated with an increased severity of flap necrosis. Despite no reports of implant loss in these studies, the delayed wound healing resulting from flap necrosis placed the patients at risk for subsequent reoperation as well as a delay in timing of adjuvant therapy.

In a retrospective review of post-mastectomy patients undergoing breast reconstruction from 2008 to 2010, Adetayo et al reported an 8.1% incidence of “never events.” Surgical site infection (7.7%) and catheter-related urinary tract infection (0.3%) accounted for the entirety of never events and predictably, diabetes was identified as a strong independent risk factor for never event occurrence. Over the 32 month study period, the authors reported an estimated $633,940 of revenue loss for the institution related to never events. The revenue loss did not include the cost of durable medical equipment such as implants which are also compromised in the setting of infection. In fact, studies have demonstrated that diabetes is an independent predictor of tissue expander loss. Implant loss considerably increases not only the financial burden to institutions, but also has a significant psychosocial impact for the patient.

**Aesthetic Breast Surgery**

While reconstructive breast operations inherently carry higher risks than elective breast procedures due to underlying disease processes, aesthetic breast surgery is not without complications. A review of 51,235 breast surgeries including augmentation, mastopexy, and breast reduction identified that patients with diabetes had a strong trend toward higher complication rates. Mastopexy, in particular, had a higher rate of infection (11%) among obese, diabetic patients compared with non-obese and non-diabetic patients (0.6%, and 1.7%, respectively). A separate review of patients undergoing cosmetic breast operations at Johns Hopkins University had similar findings reporting diabetes as a statistically significant predictor of overall complication rate on univariate analysis. This study also highlights the important fact that, of the 8000 patients included in the study, there was a 14.9% overall incidence of diabetes mellitus, a number much higher than might be expected in this relatively young patient cohort.
Abdominoplasty/Panniculectomy

Body contouring procedures are commonly performed following massive weight loss and have been shown to significantly improve quality of life after bariatric surgery.26 Unfortunately, body contouring procedures such as abdominoplasty have been associated with complication rates of nearly 40% with the most common problems being either wound-related or the development of a seromas.29 In a retrospective review of patients undergoing panniculectomy or abdominoplasty, 15% developed surgical site infections with diabetes mellitus found to be an independent predictor.30 Diabetes was also associated with a significantly higher rate of wound healing problems in another review of abdominoplasty patients.31 While diabetes has a clear association with poor outcomes following abdominoplasty or panniculectomy alone, concomitant ventral hernia repair has been found to exacerbate this negative effect. In a review of patients undergoing either abdominoplasty alone or abdominoplasty with simultaneous ventral hernia repair, diabetes was a predictive variable for complications.32 The cohort undergoing abdominal contouring with hernia repair had a higher complication rate as compared to the abdominoplasty alone cohort (18.3% vs 9.8%, \(P < .001\)). In another large study of patients undergoing panniculectomy and ventral hernia repair, Fischer et al found a 1.96 times increased odds of developing a postoperative complication in the setting of diabetes.33 Although not surprising, given the increased number of comorbidities associated with the majority of patients undergoing body contouring procedures, these findings highlight the importance of optimizing glycemic control in the perioperative period.

Free Tissue Transfer

The hyperglycemic complications associated with free tissue transfer are less well established. Experimental microvascular animal models have demonstrated the association of hyperglycemia with a slower rate of endothelialization and decreased intimal repair following vascular anastomosis.34-36 Despite these findings, a 100% technical success rate for free tissue transfer are less well established. Experimental microvascular animal models have demonstrated the association of hyperglycemia with a slower rate of endothelialization and decreased intimal repair following vascular anastomosis.34-36 Despite these findings, a 100% technical success rate for 1-week flap survival and vascular patency was demonstrated in a streptozotocin-induced diabetic rat model and concluded diabetes should not be considered a contraindication to free tissue transfer.36 Additional clinical studies have since demonstrated that free tissue transfer in diabetic patients is feasible without an increased risk of complications.37-40 However, other authors have shown a significant association with adverse outcomes such as skin flap necrosis, donor site complications, and parenchymal fibrosis.41-43

The conflicting evidence in the literature regarding hyperglycemic effects on free tissue transfer may be attributable to differing inclusion criteria and management of diabetes as a predictive variable. While most studies analyzing factors predictive of free flap failure include diabetes as a categorical variable, these studies did not review the degree of glycemic control achieved before, during, or after surgery. In a large review of patients undergoing free transverse rectus abdominis myocutaneous flaps, the authors excluded all patients with abnormal blood sugar levels. In this cohort of patients with optimal glycemic control, they found that blood glucose levels were not predictive of complications.40 However, the outcomes for patients with abnormal glycemic levels are less well established. Most studies which demonstrate an association between diabetes and postoperative complications focus only on diabetes as a comorbidity without reference regarding the degree of glycemic control (ie, perioperative glucose or HbA1c values). Without appropriate data addressing the degree of glycemic control as a predictive variable, definitive conclusions regarding the association between diabetes and complications following microvascular reconstruction cannot be drawn.

RECOMMENDED INSTITUTIONAL GUIDELINES FOR PLASTIC SURGERY PATIENTS

Recently, a multisite task force was initiated to standardize the care of all adult diabetic patients undergoing surgery within the Mayo Clinic Enterprise.44 The institutional protocol is based on clinical practice guidelines from the Endocrine Society45 with adaptations made by a multidisciplinary team in order to optimize perioperative glycemic control within our system. These practice recommendations have been implemented with the plastic surgery department at Mayo Clinic Florida.

Preanesthesia Medical Exam

The initial step in the perioperative management of hyperglycemia is the identification of patients who are at risk. The recommended process starts during the preanesthesia medical evaluation for screening and monitoring (Table 1). Blood glucose is screened in every surgical patient. Any

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<td><strong>Outpatient</strong></td>
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HgbA1c, hemoglobin A1c; qAC, before every meal; qHS, every night; NPO, nothing by mouth.
preoperative glucose > 140 g/dL warrants continued monitoring for an additional 24 to 48 hours. Patients receiving corticosteroids or octreotide should also be monitored for a minimum of 24 to 48 hours. Newly diagnosed diabetics should be monitored qAC (before each meal) and qHS (every night) or q4 to 6 hours while NPO. The goal of treatment it to achieve qAC blood sugars below 140 g/dL, random blood sugars below 180 g/dL, and to avoid hypoglycemia (defined as glucose below 70 g/dL).

All known diabetic patients should have a Hemoglobin A1c (HbA1c) documented within three months of surgery. If the HbA1c is >8.0%, the patient is referred to their primary care provider for glycemic control optimization prior to elective surgery. In the setting of an urgent operation, endocrine consultation is recommended during the inpatient encounter (Figure 1).

Other adjunctive measures taken in the clinic setting include the provision of patient education materials outlining specific instructions regarding diet and management of diabetes medications prior to surgery. Patients are educated regarding the risk of hypoglycemia while fasting for a procedure. All oral diabetes medications are to be held on the day of surgery. Patients receiving basal insulin such as glargine or detemir insulin are instructed to take their usual dose of long-acting insulin for surgeries scheduled before 10 AM and one half their regular dose for surgeries scheduled later than 10 AM. Patients on intermediate acting insulin (NPH) take one half of their usual dose on the day of surgery. Pre-mixed insulins such as 70/30 and 75/25 are avoided on the day of surgery as well as rapid insulins such as insulin aspart and lispro. Patients with insulin pumps are instructed to continue with their basal insulin rates without a morning bolus on the day of surgery.

**Preoperative Care Unit**

On the day of surgery, blood glucose levels are checked at the time of admission then every 2 hours while NPO. This is facilitated by the availability of point of care glucose testing in the preoperative holding area. A thorough intake evaluation regarding usage of recent oral anti-hyperglycemic medications or insulin is also very important. For confirmed blood glucose levels ≤70 mg/dL, treatment via administration of intravenous dextrose is initiated (Appendix A; Appendices A-C are available online as Supplementary Material at www.aestheticsurgeryjournal.com). For levels ≥140 mg/dL, two options for immediate treatment are available. First, sliding scale insulin correction can be initiated (Supplementary Appendix B). Sliding scale insulin may be administered according to either a mild or moderate intensity scale. The intensity of each scale is based on an insulin correction factor of 40 and 20 for the mild and moderate scales, respectively. Second, for patients who have not had basal insulin within 24 hours, the patient may be given a dose of long acting basal insulin (Figure 2). If basal insulin supplementation is chosen, patients controlled by oral diabetic medications and basal insulin are given half of their usual basal dose (oral diabetic medications are not indicated). Patients controlled by basal insulin only should receive full basal insulin dose.

**Intraoperative Management**

To ensure compliance with protocol recommendations, the surgical “time-out” requires verbal confirmation regarding the diabetic status of the patient and the current glucose level. For diabetic patients, interval assessment of blood glucose is performed every two hours while receiving sliding scale insulin correction. The assessment interval changes to hourly when using an insulin infusion, which is the treatment of choice for critically ill patients. Intraoperative blood glucose levels ≤70 mg/dL require initiation of a hypoglycemic therapy protocol (Supplementary Appendix A) and levels ≥140 mg/dL warrant insulin administration (Supplementary Appendix B). Bolus intravenous insulin dosing is not recommended due to the increased risk of hypoglycemia and inadequate control of hyperglycemia. (Figure 3).
Postanesthesia Care Unit

Blood glucose assessment and treatment continues every 1 to 2 hours throughout the postanesthesia care unit (PACU) stay. Intravenous fluids without dextrose are utilized except in patients with prolonged NPO status, blood glucose levels <70 mg/dL, or when required for medication mixing. Once discharge criteria are met for the PACU, nursing staff are advised to confirm the presence of an appropriate insulin correction scale prior to discharging the patient. Nursing report given to the receiving team must include the time and dose of last insulin administration as well as the patient’s most recent blood glucose measurement. Endocrine consultation may be required by the surgical team.

For patients leaving the PACU on an insulin infusion, hourly blood glucose checks are continued. In the circumstance that a patient is transitioned to the floor on an intravenous insulin infusion, appropriate measures should be taken to guarantee the necessary level of monitoring. Recommendations for transitioning to subcutaneous insulin on the general floor are dependent upon the patient’s preoperative regimen (Figure 4). Patients with Type I diabetes should be administered the subcutaneous basal insulin injection 2 to 3 hours before discontinuing the continuous IV infusion. Diabetic patients controlled preoperatively using oral medications only are transitioned dependent on the intravenous insulin requirements. For patients requiring less than 2 unit/hour and maintaining a blood glucose level ≤140 mg/dL, intravenous insulin is discontinued and a sliding scale subcutaneous insulin is initiated with blood glucose checks four times daily. For patients with greater than 2 unit/hour insulin and/or blood glucose levels ≥140 mg/dL require administration of basal subcutaneous insulin injection based on the IV insulin requirements over the previous 12 to 18 hours. The intravenous insulin can be discontinued 2 to 3 hours after administration of the basal subcutaneous insulin injection and a sliding subcutaneous insulin scale is initiated with glucose checks every 6 hours.

Patients utilizing basal insulin therapy preoperatively are transitioned to their home regimen of basal subcutaneous insulin dose or a weight based calculation dose (Supplementary Appendix C). The intravenous insulin can be discontinued 2 to 3 hours after administration of the basal subcutaneous insulin injection and a sliding subcutaneous insulin scale can be initiated with glucose checks every 6 hours.

Postoperative Inpatient Phase

Once on the floor, blood glucose targets transition to a fasting glucose level of <140 mg/dL and random blood glucose level of <180 mg/dL. Blood glucose should be
checked upon arrival to the surgical unit, before meals and at bedtime. An important and often overlooked measure is to abstain from including dextrose in maintenance IV fluids for diabetic patients unless they have a prolonged NPO status, blood glucose level ≤70 mg/dL, or require dextrose for another medication.

For patients who are diet controlled or on oral medications exclusively, sliding scale insulin is recommended unless blood glucose is >180 mg/dL twice in a 24 hour period. In this situation a weight based insulin regimen (Supplementary Appendix C) is recommended. While the general practice is to avoid oral hyperglycemic medications while inpatient, plastic surgery patients with a history of controlled blood glucose levels at home (HbA1c < 8%) often meet criteria for restarting their preoperative regimen. In order to restart oral medications, the renal and liver function must be within normal range, the expected length of stay must be <48 hours, and the patient must tolerate a diabetic diet. Patients that were insulin-dependent prior to surgery often require basal insulin calculated according to a weight based regimen (Supplementary Appendix C). Half of the total daily insulin requirement is given as a basal dose. If elevated blood glucose persists despite basal insulin, a prandial regimen is added supplying the other half of the total daily insulin requirement divided into three doses (Figure 5).

**Discharge Management**

Preparation for discharge is a crucial period for the management of perioperative hyperglycemia. Any adjustments that were made to the patient’s hyperglycemic regimen must be reconciled prior to discharge. Dietary modifications and frequency of home glucose testing should also be clarified. Appropriate follow up with a primary care provider or endocrinologist is also essential.

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**Figure 3.** Algorithm for intraoperative glycemic control BG, blood glucose; gtt, continuous intravenous administration; PACU, postanesthesia care unit; Q1, every 1 hour; SQ, subcutaneous. *Adapted from Mayo Clinic Provider Algorithm based on Endocrine Society Glycemic Control Guidelines.*

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Glycemic Control for Outpatient Procedures

The primary approach to the diabetic patient undergoing an outpatient procedure is focused on obtaining appropriate glycemic control prior to the scheduled operative date. Patients undergoing outpatient procedures should have a documented HbA1C value within the last three months. The goal value is <8.0% and if this goal is not achieved, the patient is referred to their primary care provider or endocrinologist to improve control prior to proceeding with surgery. Following the procedure for patients who are deemed operative candidates, point of care glucose testing is performed in the postanesthesia care unit. Hyperglycemic episodes are treated with sliding scale insulin according to the aforementioned protocol. Prior to discharge, random glucose levels should be maintained below 180 mg/dL.

Figure 4. Algorithm for postanesthesia care unit (PACU) glycemic control. BG, blood glucose; DM, diabetes mellitus; PACU, postanesthesia care unit; SQ, subcutaneous. *Adapted from Mayo Clinic Provider Algorithm based on Endocrine Society Glycemic Control Guidelines."
Patients are counseled to continue monitoring blood glucose at home according to their standard practice. Oral and fast acting anti-hyperglycemic medications are resumed on the night following surgery.

**DISCUSSION**

In this article, we reviewed the perioperative glycemic control protocol which has been in effect at our institution since 2013. This protocol, developed by an interdisciplinary team of surgeons, anesthesiologists, and endocrinologists, has served the intended purpose of standardizing the perioperative management of diabetic patients undergoing surgery. In our own plastic surgery practice we have found the protocol to be extremely useful in standardizing the perioperative care of the diabetic patient. Though there are currently enterprise-wide prospective studies analyzing outcomes since implementation of the protocol, one of the limitations of this review is the lack of outcomes data specific to our plastic surgery population. Preliminary results from our institution have demonstrated that 10.3% of our plastic surgery population has diabetes. Intraoperative hyperglycemia among all surgical specialties was reduced from 40% to 18% comparing 2012 with 2015 data. Within plastic surgery alone, intraoperative hyperglycemia was reduced by an absolute value of 50%. We have not yet correlated this improvement with postoperative outcomes such as wound healing or infection rates, but we anticipate that this will have a substantial impact. Given the cost of complications following aesthetic surgery, which often includes hospital admission or re-operation, there is a significant financial incentive to control surgical quality. Perioperative glucose management is one factor that impacts surgical outcome that we are able to influence as providers. The authors of this review describe one protocol for how to approach this problem in a standardized method. Despite a clear association between diabetes and postoperative complications, the impact of glycemic control on plastic surgery outcomes has not been extensively studied in the currently available literature. We hope that this review serves the purpose of bringing to light the importance of addressing this modifiable factor to improve quality of care.

**CONCLUSIONS**

Diabetes is a common comorbidity with documented negative outcomes following surgery. Plastic surgery is not exempt from the negative impact of this disease on factors such as wound healing, infection risk, and tissue perfusion. Quality has become a priority driving improvement in surgical outcomes. Controllable risk factors such as perioperative hyperglycemia must be addressed to improve safety and outcomes. Adoption of a standardized protocol

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**Figure 5.** Algorithm for postoperative inpatient glycemic control. BG, blood glucose; DM, diabetes mellitus; SQ, subcutaneous; TDD, Total Daily Dose; *Adapted from Mayo Clinic Provider Algorithm based on Endocrine Society Glycemic Control Guidelines.45

∞ Total Daily Dose basal insulin calculation formula is described in Supplementary Appendix C.
provides a structure for consistently addressing perioperative glucose control.

**Supplementary Material**

This article contains supplementary material located online at www.aestheticsurgeryjournal.com.

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**REFERENCES**


