

Diabetes and its negative impact on outcomes in orthopaedic surgery

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Abstract

An estimated 285 million adults (aged 20-79 years) worldwide were diagnosed to have diabetes mellitus (DM) in 2010, and this number is projected to grow to 439 million adults by the year 2030. Orthopaedic surgeons, regardless of their subspecialty interest, will encounter patients with DM during their career since this epidemic involves both developed and emerging countries. Diabetes results in complications affecting multiple organ systems, potentially resulting in adverse outcomes after

orthopaedic surgery. The purpose of this review is to discuss the pathophysiology of DM and its potential for impacting orthopaedic surgery patients. Diabetes adversely affects the outcome of all orthopaedic surgery subspecialties including foot and ankle, upper extremity, adult reconstructive, pediatrics, spine surgery and sports medicine. Poorly controlled diabetes negatively impacts bone, soft tissue, ligament and tendon healing. It is the complications of diabetes such as neuropathy, peripheral artery disease, and end stage renal disease which contributes to adverse outcomes. Well controlled diabetic patients without comorbidities have similar outcomes to patients without diabetes. Orthopaedic surgeons should utilize consultants who will assist in inpatient glycemic management as well as optimizing long term glycemic control.

Key words: Diabetes; Orthopaedic surgery; Outcomes; Complications; Neuropathy

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Core tip: Diabetes is associated with adverse outcomes following orthopaedic surgery. The complications of diabetes such as poor glycemic control, neuropathy, end stage renal disease and neuropathy contribute to adverse outcomes. These adverse outcomes include surgical site infections, impaired wound healing, pseudarthrosis, hardware and implant failure and medical complications. Patients with diabetes who undergo orthopaedic surgery should receive optimal medical management prior to elective surgery in order to minimize complications.

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INTRODUCTION

In 2010 nearly 300 million adults were estimated to have diabetes mellitus (DM) globally, and this number is projected to grow to 439 million adults by the year 2030^[1]. Diabetes is associated with an enormous economic burden and the International Diabetes Federation (IDF) projected that the global health expenditures to prevent and treat DM and its complications totaled 376 billion United States dollars in 2010^[1]. By 2030, IDF estimates that expenditures will exceed 490 billion United States dollars^[1]. Orthopaedic surgeons, regardless of their subspecialty interest, will encounter patients with DM during their career since this epidemic involves both developed and emerging countries. Diabetes results in complications affecting multiple organ systems, potentially resulting in adverse outcomes after orthopaedic surgery. Significant alterations in glucose metabolism occur during periods of heightened stress such as major surgery, trauma and sepsis. It has been reported that diabetic patients undergoing surgery are at risk for increased morbidity and longer hospital stays. Surgical patients with DM are estimated to utilize 45% excess bed days compared to people without DM admitted to medical wards^[2-4]. In diabetic patients undergoing non-cardiac general surgery, the peri-operative mortality rate is significantly higher than the mortality seen in patients without DM^[5]. Orthopaedic surgeons who treat extremity infections may identify DM in patients not previously diagnosed with DM. A retrospective review of 1166 orthopaedic admissions identified 385 patients with an admission hyperglycemia, identified by a serum glucose \geq of 120 mg/dL^[6]. Only 45% of the hyperglycemic patients (174) were known to have DM prior to admission patients^[6]. The purpose of this review is to discuss the pathophysiology of DM and its potential for impacting orthopaedic surgery patients.

PATHOPHYSIOLOGY

Diabetes mellitus can be broadly classified into three types, based on the onset of symptoms and the absolute need for insulin replacement. Patients who have an absolute requirement for insulin, secondary to autoimmune dysfunction of the pancreatic beta cells, have type 1 DM. The vast majority of patients have type 2 DM which is associated with older patients, elevated body mass index (BMI), genetic predisposition, history of DM during pregnancy, less active individuals, and certain ethnic groups. Four out five patients with type 2 DM have an elevated BMI. Children and adolescents, particularly from certain ethnic and racial groups (African - American, Mexican American, and Pacific Islander), are being diagnosed with type 2 DM at an increasing rate. During the early stages of type 2 DM the pancreas usually produces insulin, however insulin resistance is present and glucose metabolism is negatively impacted. A small percentage of pregnant women develop

gestational DM and 40% to 60% of these patients will ultimately develop type 2 DM within 5 to 10 years.

The end result of DM, regardless of the etiology, is hyperglycemia. The primary energy source for our body is glucose, and glucose is stored as glycogen in the liver and skeletal muscle. Insulin facilitates glucose uptake into the peripheral cells, assisting with the storage of glycogen. While patients with type 1 DM have an absolute need for insulin replacement, patients with type 2 DM initially produce insulin, sometimes in high amounts. The problem is so called "insulin resistance", in which the cells become less sensitive to insulin and hyperglycemia results. Stress hyperglycemia can occur in hospitalized patients without a previous history of DM and is defined as any serum glucose $>$ 140 mg/dL. Although this hyperglycemic state typically resolves with abatement of the heightened stress, approximately 60% of patients may ultimately develop DM^[7]. Surgery, trauma and infection stimulate release of counter regulatory hormones such as glucagon, epinephrine, cortisol, and growth hormone, resulting in derangement in normal carbohydrate metabolism. This dysfunction may result in a decrease in peripheral tissue insulin uptake (*i.e.*, resistance), gluconeogenesis in the liver, decreased efficiency of tissue glucose utilization and relative insulin deficiency^[7]. Both observational studies and prospective studies in intensive care unit (ICU) patients have demonstrated a correlation between hyperglycemia and adverse outcomes during the hospitalization^[8,9]. Hyperglycemia results in inhibition of Interleukin 1 release from macrophages, impaired phagocytosis and diminished production of oxygen radicals from neutrophils, all of which contribute to a relative immunodeficiency.

Hyperglycemia at the time of admission in patients with life threatening medical problems is associated with higher mortality rates when compared to normoglycemic patients. Umpierrez *et al*^[9] reported that nearly 40% of patients admitted to the hospital had abnormally high serum glucose levels, and that patients with new onset hyperglycemia had a five times higher rate of mortality while hospitalized compared to patients with established DM. Patients with newly diagnosed DM remained in the hospital longer, required more intensive care and had to be discharged to skilled nursing units more often than patients with established DM. Orthopaedic surgeons should be aware that some patients will be diagnosed with DM during their admission, and this may be associated with inferior outcomes after orthopaedic surgery.

COMPLICATIONS OF DIABETES

Complications associated with DM result from macrovascular and microvascular disease (Table 1). Many of these complications do not directly impact the musculoskeletal system; however the indirect

Table 1 Complications of diabetes potentially affecting orthopaedic surgery patients

Retinopathy
Visual impairment leading to falls
Peripheral neuropathy
Balance issues
Gait abnormalities
Lack of protective sensation
Increased risk of surgical site infection
Increased risk of nonunion
Peripheral artery disease
Impaired lower extremity blood supply leading to faulty healing
End stage renal disease
Metabolic bone disease
Anemia of chronic disease
Poorly controlled diabetes (hyperglycemia)
Increased risk of surgical site infection
Impaired bone and soft tissue healing

effects can be significant. Cardiovascular complications such as coronary artery disease, hypertension and cerebrovascular accidents are 100%-300% more likely in patients with DM. Diabetes is associated with a two to four fold increase in cardiovascular disease including hypertension, coronary artery disease and stroke^[2,4]. Patients with retinopathy and visual impairment may injure their lower extremity due to inability to visualize objects in their path during ambulation. Patients with neuropathy may fall second to balance issues resulting in musculoskeletal trauma. Patients with diabetic nephropathy may have vitamin D deficiency that potentially weakens the osseous structures. Finally, macrovascular disease may result in atherosclerosis and can impede wound healing.

There is evidence of abnormal blood flow patterns in the neuropathic diabetic foot unrelated to ischemia. A study of patients with Type 1 DM and peripheral neuropathy demonstrated that the normal triphasic pattern of arterial blood flow was lost despite normal pulse wave velocities^[10]. No significant stenosis was identified in any of the arteries studied including distal evaluation of the dorsalis pedis and posterior tibial arteries^[10]. The mean great toe pressure in patients with DM was 64 mmHg as compared with 98 mmHg in controls. A linear correlation of decreasing toe pressures with increasing severity of neuropathy was seen ($R = 0.7$), suggesting that changes exist in the blood flow patterns in young patients with DM and neuropathy, even in the absence of lower limb ischemia. These changes may not be clinically meaningful in patients who do not undergo surgery, but may become very important if a surgical wound is created. The prevalence of peripheral artery disease (PAD) in patients aged ≥ 40 years with DM is estimated to be 10% compared to 5% in the general population, and the prevalence increases with advancing age^[11]. Diabetic related atherosclerosis has a predilection for affecting the arteries distal to the

popliteal trifurcation, and assessment of the pulses is recommended in patients undergoing lower extremity surgery.

TREATMENT OF HYPERGLYCEMIA

The management of inpatient glycemic control strives to avoid hyperglycemia, however it is generally agreed that hypoglycemia is to be avoided. Randomized studies of inpatients have demonstrated that optimal glycemic management is associated with improved outcomes^[12,13]. During heightened periods of stress (surgery, sepsis and infection), insulin is the recommended method to achieve glycemic control, even in patients who did not use insulin prior to admission. In some cases, insulin requirements are greatly increased due to stress hyperglycemia^[13]. Recent guidelines on glycemic control have focused on both the ICU setting and non-critical inpatient care settings^[4,12,13]. These guidelines are the result of input from representatives of major key organizations involved in the inpatient care of DM^[4,13]. The Endocrine Society recommends pre-prandial glucose levels of < 140 mg/dL and random serum glucose levels of < 180 mg/dL in patients not admitted to ICU^[13]. Serum glucose levels of < 150 mg/dL are recommended in ICU patients, ideally maintained with intravenous insulin and careful monitoring^[14]. Regardless of the clinical setting (ICU vs non-ICU), hypoglycemia is to be avoided (blood glucose ≤ 70 mg/dL)^[4,13,14]. Hyperglycemia is very common in ICU patients, and up to 80% of these patients may not have been diagnosed with DM prior to the ICU admission^[7]. Stress induced hyperglycemia may manifest in orthopaedic surgery patients after major surgery, sepsis or trauma.

MUSCULOSKELETAL MANIFESTATIONS OF DIABETES

Disturbances of gait

Patients with DM often have limitation of motion in the foot and ankle, resulting in biomechanical abnormalities^[15]. This reduction in joint motion is more pronounced in diabetic patients with peripheral neuropathy, and has been observed during the propulsive and swing stages of gait^[15]. Alterations in foot biomechanics and balance issues secondary to peripheral neuropathy are important factors which could lead to ground level falls and trauma (Table 2).

General issues

Diabetic polyneuropathy can result in balance and stability issues^[16]. Diabetes mellitus, independent of neuropathy, could have a direct effect on postural control during standing after a self-induced forward reaching movement^[16]. Patients with DM have been found to have thickening of the Achilles tendon and plantar fascia when compared to control patients, and

Table 2 Impact of diabetes on orthopaedic surgical subspecialties

Foot and ankle surgery
Increased risk of surgical site infection
Increased risk of nonunion, malunion and hardware failure
Increased risk of neuropathic ulcers
Spine surgery
Increased risk of surgical site infection
Increased risk of nonroutine discharges
Sports medicine
Impaired healing of soft tissues (ligaments and tendons)
Spontaneous necrosis of muscle
Total joint arthroplasty
Increased risk of surgical site infection
Increased risk of nonroutine discharges
Upper extremity
Increased risk of nerve compression syndromes
Increased risk of overuse syndromes
Inferior outcomes in rotator cuff repair and frozen shoulder

these findings may contribute to balance issues^[17].

IMPACT ON SOFT TISSUES TENDON HEALING

Tendons in patients with DM tend to be thicker and stiffer than normal tendons resulting in alterations in the normal mechanical properties^[18]. An experimental pig model evaluating patellar tendons found that proteoglycan synthesis by tenocytes was reduced in tendons exposed to high concentrations of glucose^[19]. Clinically, this may explain the high rate of tendon pathology seen in patients with DM^[19]. A diabetic rat model of patellar tendon pathology has also demonstrated a decrease in Young's modulus and high rate of intrasubstance failure^[20].

Steroid injections are commonly performed for various musculoskeletal problems, and transient elevations in serum glucose levels can occur^[21]. A study of hand surgery patients reported that a 1-mL triamcinolone acetonide injection resulted in statistically significant elevations in serum glucose on days 1, 5, and 6 d after injection. Patients with DM should be advised that a transient rise in serum glucose levels will occur after a corticosteroid injection^[21]. This finding is applicable to other areas of the musculoskeletal system where local injections of corticosteroids are used.

BONE HEALING AND METABOLISM

Alterations in bone healing as a result of DM have been demonstrated in both the clinical setting and laboratory models. Diabetes has been found to cause bone mineral alterations in a laboratory rat model^[22]. A reduction in bone mineral and crystal formation has been identified in the tibial metaphysis of diabetic rats. This results in biomechanical changes that diminishes stiffness, torsional strength and energy absorption of the fracture callus^[22]. Beam *et al*^[23] studied fracture

callus formation in diabetic rats, and observed that poor glycemic control negatively impacted fracture callus by inhibiting chondrocyte production and impeding ossification of the immature enchondral bone. Diabetic rats with optimal glycemic control did not experience these changes, and the mechanical properties of the bone were similar to non-diabetic animals^[23]. Poorly controlled DM also decreases important cytokine production and reduces new blood vessel formation at the site of callus^[24].

FOOT AND ANKLE SURGERY

The implications of DM on outcomes in orthopaedic surgery have been evaluated most extensively in foot and ankle surgery. Diabetes has a high predilection for affecting the foot and ankle largely due to the complications of DM such as neuropathy and PAD. The incidence of diabetic foot ulcers is 2% and 15%-25% of patients will develop a foot ulcer at some point in their life^[25]. Once an ulcer develops, the risk of infection rises dramatically, and it has been estimated that 85% of non-traumatic amputations are due to DM^[26]. Severe diabetic foot infections, manifested by the presence of systemic inflammatory response syndrome, may require transtibial amputation in nearly 20% of patients^[27].

Charcot neuroarthropathy (CN) is relatively unique to the foot and ankle and is associated with decreased quality of life and high risk of foot ulceration^[28]. Patients with CN and foot ulcers have a 12 times higher risk of major amputation than patients without ulcers^[29]. High rates of complications, both infectious and noninfectious, have been observed in CN patients undergoing surgical correction^[30]. Elective foot and ankle surgery in patients with DM is associated with higher complication rates. Patients with complicated DM (neuropathy, PAD or nephropathy) have a seven times higher likelihood of surgical site infection (SSI) compared with non-diabetic patients without neuropathy and nearly a four times higher likelihood of SSI compared with patients with uncomplicated DM^[31]. Peripheral neuropathy and a hemoglobin A1c of $\geq 8\%$ were independently associated with SSI^[31].

Arthrodesis surgery is commonly performed for foot and ankle problems in patients with DM, and complications of surgery are higher in diabetic patients^[32]. A retrospective review compared 74 diabetic patients and 74 non-diabetic patients. Diabetes, tobacco use and peripheral neuropathy were associated with higher complication rates. Diabetic patients experienced higher rates of infectious and noninfectious complications. Complication rates were also higher in patients with suboptimal short and long term glycemic control^[32].

Ankle fractures in patients with DM are also associated with higher complication rates when compared to patients without DM^[33,34]. Patients with complicated DM (neuropathy, PAD or and/or nephropathy) had higher rates of non-infectious complications (malunion,

nonunion or CN) and were 5 times more likely to require revision surgery when compared to patients with uncomplicated DM. Many diabetic patients are not aware that they have neuropathy and/or PAD until they experience a postoperative complication.

ORTHOPAEDIC TRAUMA

Stress hyperglycemia in orthopaedic trauma patients is associated with higher rates of postoperative infections^[35-38]. A recent retrospective study of 110 orthopaedic trauma patients without a history of DM were evaluated based on the level of postoperative hyperglycemia^[35]. Patients who manifested a serum glucose greater than 220 mg/dL had a 25% infection rate, including wound infections, pneumonia, urinary tract infections, bacteremia or severe sepsis. Perioperative glucose levels greater than 220 mg/dL increased the likelihood of infection by a factor of seven in orthopaedic trauma patients with no known history of DM^[35].

Another study evaluated 187 consecutive critically injured non-diabetic orthopaedic trauma patients who were admitted to the intensive care unit^[37]. Multivariable regression testing demonstrated a significant relationship between hyperglycemia and SSI, leading the authors to conclude that stress induced hyperglycemia was an independent predictor of SSI in nondiabetic, critically injured orthopaedic trauma patients^[37]. The same authors evaluated non-critically injured orthopaedic trauma patients^[38]. Patients with hyperglycemia (blood glucose > 140 mg/dL) had a 4.9 times increased odds of a SSI when compared to patients without hyperglycemia. Patients with two or more blood glucose levels of > 200 mg/dL experienced a 170% increased risk of SSI compared to patients who glucose remained below 200 mg/dL^[38]. Diabetes also is associated with increased risk of hip fractures in both men and women and negatively impacts the outcomes of hip fracture treatment^[39,40]. At the time of admission, diabetic patients with hip fractures were more likely to use assistive devices (canes and walkers) and were more limited in ambulation than patients without DM^[39]. After surgery, cardiac complications and decubitus ulcers were more common in diabetic patients. Although diabetic patients had a significantly longer hospital stay than non-diabetic patients, no difference in surgical complication rates were observed. Follow up at one year demonstrated that diabetic patients experienced a similar level of functional recovery compared to patients without DM^[39].

A study of hip fractures in patients with and without DM demonstrated that prior to hip fracture, diabetic complained of more pain, were less healthy and more likely to use assistive devices^[41]. Reoperation rates and medical complications were similar during the first year, however, cardiac and renal complications were more common in diabetic patients by the second year of follow up^[41]. Although diabetic patients were

more likely to complain of severe hip pain at 4 mo, by 12 mo patients with DM were more likely to return to independent living. Ultimately patients with and without DM had similar levels of ambulation, ADL's and living conditions^[41].

SPORTS MEDICINE

Diabetic patients who participate in athletic activity have to be vigilant when managing insulin requirements, carbohydrate intake and the impact of athletic activity on serum glucose levels^[42]. Prior to participating in sports, a thorough examination is necessary, and insulin dosages may need to be adjusted based on the level of activity and carbohydrate intake. Risk assessment for both hypoglycemia and ketoacidosis is mandatory based on the level of competition expected^[42]. Athletic activity and exercise improve glycemic control and has a positive impact on risk factors for cardiovascular disease, independent of any change in body mass index and fat mass. Exercise appears to enhance the effects of insulin on skeletal muscle, liver and fat. As the diabetic population increases, more and more patients will employ exercise as a method to achieve ideal body weight and glycemic control since encouraging results have been demonstrated with even moderate increases in physical activity. Orthopaedic surgeons can expect to see an increase in overuse syndromes in this population.

Claudication like symptoms in diabetic patients may be caused by PAD, radiculopathy or chronic exertional compartment syndrome of the leg, and a careful history and examination is necessary to arrive at the correct diagnosis^[43]. Seventeen patients with DM and leg pain during walking underwent intramuscular pressure measurements during exercise. Diabetic patients demonstrated significantly higher compartment pressures than a control group of non-diabetic patients with exertional compartment syndrome ($P < 0.05$)^[43]. Despite having higher compartment pressures, patients with DM achieved satisfactory results with release of the involved compartments.

TOTAL JOINT ARTHROPLASTY

Type 2 DM and obesity are commonly related and it is not surprising to see these comorbidities in patients with osteoarthritis. Both morbid obesity and DM are independently associated with deep infection after primary total knee arthroplasty^[44]. Diabetes and hyperglycemia have been shown to negatively impact outcomes in several studies of joint arthroplasty. Diabetic patients with a preadmission blood glucose of at ≥ 200 mg/dL had an increased risk of pulmonary embolism by 200% when compared with patients with a blood glucose < 110 mg/dL^[45]. The risk of thromboembolism after total knee arthroplasty was double that of total hip arthroplasty^[45].

Bolognesi *et al*^[46] reported that diabetic patients

undergoing primary and revision hip and knee arthroplasty had fewer routine discharges and higher hospital charges for all procedures. Pneumonia, cerebrovascular accidents and need for blood transfusions were more likely in patients with DM^[46]. In an effort to reduce the rate of postoperative infections, a prospective single-blinded randomized study of 78 patients evaluated the role of antibiotic-impregnated cement during primary total knee arthroplasty in patients with DM^[47]. No patients who received the cefuroxime impregnated cement experienced an infection compared to five infections (13.5%) in patients who did not receive antibiotic cement ($P = 0.021$)^[47]. Patients with type 1 DM had longer hospital stays and higher costs than patients with type 2 DM following hip and knee arthroplasty^[48]. Surgical (hemorrhage and wound infection) and nonsurgical complications (heart attack, pneumonia, urinary infections and death) were more common in patients with type 1 DM. The authors postulated that these findings were due to the differences in the duration of DM and their underlying pathologies. Since Patients with type 1 DM carry more significant overall perioperative risks and require more health care resources compared with patients with type 2 DM following hip and knee replacement^[48].

However, not all studies have demonstrated inferior results of joint arthroplasty in patients with DM. A study of primary total knee replacement patients classified the patients as having no DM, controlled DM with HbA1c < 7%, or uncontrolled DM with HbA1c $\geq 7\%$ ^[49]. Revision joint arthroplasty, deep wound infection and thromboembolism were not found to be significantly higher in diabetic patients (controlled and uncontrolled) when compared to non-diabetic patients^[49]. Another study of 275 patients with DM who underwent total knee arthroplasty found that self-reported outcome scores and patient satisfaction were not inferior compared to patients without DM^[50]. The authors acknowledged that diabetic patients had a worse postoperative outcome because of concurrent comorbidities such cardiovascular disease, liver disease, anemia, depression and back pain^[50].

PEDIATRIC ORTHOPAEDICS

Increasingly, adolescents are being diagnosed with type 2 DM and pediatric orthopaedic surgeons potentially will encounter these patients in practice. Bowen *et al*^[51] associated obesity with slipped capital femoral epiphysis, and tibia vara and DM. The 55 children with DM had a mean BMI of 36.

UPPER EXTREMITY

Several conditions of the hand have been associated with DM such as carpal tunnel syndrome, Dupuytren disease, trigger digits, and limited joint mobility^[52]. Diabetes mellitus increased the risk of Hand-Arm

Vibration Syndrome by a factor of 1.5 and Dupuytren's disease by a factor of 1.7 in a large cohort of miners^[53]. Another controlled study reported higher rate of Dupuytren's disease, tenosynovitis, carpal tunnel syndrome and reduced joint motion in patients with DM compare to patients without DM^[53]. Several factors were associated with increased severity of the pathology including the use of insulin, older patients, longer duration of DM and microangiopathic changes^[54].

Diabetic patients who undergo arthroscopic surgery for adhesive capsulitis of the shoulder have inferior results when compared to non-diabetic patients^[55]. One study reported the results of arthroscopic rotator cuff repair in patients with DM, while showing improvement, do not achieve the same level of functional recovery as seen in patients without DM^[56]. Another retrospective controlled study of arthroscopic rotator cuff repair reported significant improvement in ROM in patients with and without DM^[57]. When comparing the two groups the authors found that patients with DM had less ROM and decreased outcome scores as compared to the non-diabetic cohort. No differences in rates of complications or recurrent tears were observed between the two groups^[57].

Hand infections in patients with DM are potentially limb threatening. Diabetic patients who present with a hand abscess had an amputation rate of 17.5%^[58]. Nearly 50% of the infections were polymicrobial and hand infections may mimic foot infections in patients with DM^[58].

SPINE SURGERY

Nonsurgical treatment

It has been demonstrated that a significant elevation in blood glucose levels occurs after epidural steroid injections, a common treatment for patients with lumbar radiculopathy^[59]. A transient rise of nearly 80% occurred, however the serum glucose level normalized with 48 h of the procedure. Diabetic patients should be advised that a temporary elevation in blood glucose is likely post injection^[59].

Lumbar surgery

A study of nearly 200000 patients who underwent lumbar spine surgery evaluated complication rates in patients with and without DM^[60]. The diabetic cohort represented 5.6% of the study population (11000 patients). Patients with DM had higher rates of infection, higher rates of nonroutine discharges, longer hospital stays, more need for blood transfusion and higher hospital charges than patients without DM^[60]. Another study of 195 patients demonstrated that DM increased the risk of a SSI by a factor of four^[61]. Similar to studies on total joint arthroplasty, not all studies regarding spinal surgery associate DM with negative outcomes. A study of 23 adult patients with noninsulin

Table 3 Take home messages for orthopaedic surgeons treating diabetic patients

Optimize the patient's medical care preoperatively
Strive for long term glycemic control of HbA1c \leq 8%
Thorough preoperative workup for cardiovascular disease
Identify anemia if present and treat accordingly if major blood loss is anticipated (<i>i.e.</i> , spine surgery or total joint surgery)
Thorough assessment of the vascular system preoperatively
If an abnormal examination is present proceed with non-invasive testing and vascular consultation
Perioperative care
Strive for inpatient glycemic control as recommended by major societies
Pre-meal glucose of < 140 mg/dL
Random glucose of < 180 mg/dL
Avoid hypoglycemia!!
Glucose levels of > 200 mg/dL have been associated with increased rates of complications in orthopaedic patients
Recognize that patients with poorly controlled diabetes and comorbidities are at increased for postoperative complications
Cardiovascular complications
Myocardial infarction
Stroke
Deep vein thrombosis and pulmonary embolism
Infection
Surgical site
Urinary tract
Pneumonia
Iatrogenic pressure ulcers
Pad bony prominences such as the sacrum and heels
Noninfectious complications
Hardware failure
Nonunion or malunion
Impaired wound healing
Inform patients that local injections of corticosteroids (trigger point injections, epidural steroid injections, <i>etc.</i>) will cause a temporary elevation in serum glucose for 24-48 h

dependent DM (matched with 23 nondiabetic patients) did not identify DM as a risk factor for perioperative complications or need for additional surgery^[62]. The results of lumbar spine decompression for spinal stenosis in 25 diabetic patients and 25 non-diabetic patients were compared after an average follow up of 3.4 years. This study did not identify any difference in outcomes, and the authors proposed that patients with DM could expect to have similar improvement in symptoms as non-diabetic patients^[63].

Cervical surgery

The impact of DM on complications after cervical spine surgery was assessed in a review of nearly 38000 patients^[64]. These patients underwent decompression and fusion for cervical myelopathy^[64]. The authors found that uncontrolled DM was an independent risk factor for poorer outcomes after cervical fusion. A retrospective controlled study of outcomes from the surgical treatment of cervical myelopathy reviewed a group of patients with DM and compared them to a cohort of patients without DM^[65]. Diabetic patients demonstrated poorer return of lower extremity neurologic function (sensory and motor) than non-

diabetic patients^[65]. Suboptimal glycemic control was associated with inferior outcomes as higher levels of preoperative Hgb A1c were associated with poorer rates of neurologic recovery^[65].

CONCLUSION

Diabetes mellitus is associated with negative outcomes across the spectrum of orthopaedic surgery and its subspecialties. The take home message for orthopaedic surgeons is to optimize preoperative, perioperative and postoperative medical management in patients with DM (Table 3). Higher rates of SSI have been observed in patients with DM, particularly in total joint arthroplasty, spine surgery and foot and ankle surgery. Higher rates of other complications such as myocardial infarction, pulmonary embolism and urinary tract infections have been demonstrated as well. Diabetic patients tend to have longer hospital stays and more non-routine discharges than patients without DM. Research produced over the past few decades indicate that DM in and of itself may not be culprit in negative outcomes. Rather, the complications of DM such as poor glycemic control, neuropathy, end stage renal disease and PAD most likely increase the risk of adverse outcomes. Patients with uncomplicated DM and optimal glycemic control generally have similar outcomes to patients without DM.

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