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Review Article

Predominantly negative impact of diabetes on spinal surgery: A review and recommendation for better preoperative screening

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Abstract

Background: For patients undergoing spine surgery, the literature attributes significant increased perioperative risks/adverse events (AE) complications, longer length of stay (LOS), and higher 30-day readmission/reoperation rates to those with diabetes. Diabetics are often divided into those with insulin dependent diabetes (IDDM), and non-insulin dependent diabetes (NIDD). However, other series also compare those with uncontrolled diabetes (UCDM) vs. those with controlled DM (CDM).

Methods: We found a marked variation in the size and quality of studies identified in PubMed regarding the impact of diabetes on spinal surgery (e.g., focusing on complications, AE, outcomes, morbidity, and mortality).

Results: Of the 197,461 lumbar fusions in one NIS (Nationwide Inpatient Sample 1988–2003), 11,000 (5.6%) diabetics (DM) had higher infection rates, transfusion rates, more pneumonias, higher in-hospital mortality rates, greater costs, and longer LOS than those undergoing similar procedures without DM. For 3726 ACS-NSQIP patients undergoing anterior cervical fusions, 270 NIDDM had more urinary tract infections and returns to the operating room; the 171 IDDM required more reoperations, 30 day readmission, and longer LOS (by 5 days) vs. 3285 non DM. Of the 5627 patients undergoing posterior cervical fusions (ACS-NSQIP), 2029 (36.1%) had AE directly related to DM. In another NSQUIP study of 51277 patients undergoing lumbar spine surgery, IDDM and NIDDM demonstrated longer LOS, plus IDDM showed more surgical AE and 30 day readmissions vs. those with no DM.

Conclusions: Patients with IDDM or NIDDM undergoing spine surgery exhibited more perioperative complications/AE/morbidity, longer LOS, and higher readmission/reoperation rates vs. non DM.

Key Words: Diabetes: spinal surgery, insulin dependent DM (IDDM), more adverse events, more complications, poorer outcomes: non-insulin dependent DM (NIDDM)

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INTRODUCTION

For patients undergoing spinal surgery, the literature attributes significantly increased morbidity, adverse events (AE), complications and even mortality to diabetes [Tables 1-3]. Many studies clearly distinguished between insulin dependent diabetics (IDDM), non-insulin

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Table 1: Increased risks of spine surgery in diabetic patients references 2007-2013

Authors year	Number of patients	Operations	Risks factors	Complications	Outcomes
Browne[2] 2007	NIS 1988-2003 Lumbar Fusions ± DM	Lumbar Fusions 197,461DM 11,000 (5.6%)	DM Increased Infections Transfusions	DM Increased Pneumonia Mortality In Hospital	DM Higher Costs Longer LOS
Walid[24] 2010	>LOS>Cost DM in spine surgery LMD, ACDF LDF DM=HbA1c =/>6.1%	72.4% non DM 14.3% unknown DM 13.3% known DM	>> Cost>>LOS For LDF Unknown DM vs. non DM	Age and BMI Higher overall Costs±DM LDF Higher cost and LOS with DM	Spine surgery should screen for DM with HbA1c
Walid[25] 2010	>LOS>Cost DM in spine surgery	787 Patients 2005-2008 Average age 54.5 LMD 237 ACDF339 LDF 211	653 patients HbA1c levels 32.5% >/=6.1% 4.3% > HbA1c and Hypothyroid	None $52,449 DM $56,176 Hypothyroid $63,278 Both $71,352	LDF LOS 5 days no comorbidities LDH LOS >6 days-hypothyroid LDH LOS >8 DM/ Hypothyroidism
Walid[26] 2011	Economics comorbidities in spine surgery	816 patients 2005–2008 Costs LMD 20.5% ACDF60.3% LDF 19.2%	Average age 54>Costs: Older patients>Comorbidities	ACDF F, >BMI, DM $34,943>BMI alone $25,633	LDF/F/DM Depression $65,782 DM $53,504 Depression $55,990 $52,249 None
O'Neill[16] 2011	SSI in Spine Fusions About 10% 110 Patients 2 Years	Vancomycin Powder + IV Antibiotics < SSI in DM Fusions	54 Control IV Antibiotics 13% SSI	56 Experimental Local/IV Antibiotics 0% SSI No complications	= Comorbidities Prior surgery DM, >BMI Deficits, OR time EBL, Level
Freedman[7] 2011	SPORT TRIAL Nonsurgical Vs. Surgery	199 DM 2206 non DM IDH, SpS, DS	DM=Older>BMI, Stroke HTN CAD	DM=Poorer outcomes for IDH Better outcomes DS and Sps	Non DM all Better outcomes ALL 3 groups, fewer complications
Cho[5] 2012	23 NIDDM 23 controls	Scoliosis surgery	Min. 2 year follow sup	Same major/minor complications	Same glucose control
Takahashi[23] 2013	41 DM vs. 124 nonDM patients >50 years old	VAS Scores Higher Non DM 29.3% DM 17.9%	>Failed Fusions DM: DM 20% Non DM 3% Same complication rate	ONLY more failed fusions DM DM > Postop Low back pain DM 39.1/non DM17.4	Longer duration of DM over 20 years and poorer glycemic control correlated with poorer outcomes

IDDM: Insulin dependent diabetes mellitus, NIDDM: Non-insulin dependent diabetes mellitus, ACDF: Anterior cervical discectomy and fusion, IONM: Intraoperative Neural Monitoring, MEP: Motor Evoked Potentials, PCT: Peripheral Conduction Time, CCT: Central motor conduction time, NHIRDT: National Health Insurance Research Database of Taiwan, PCF: Posterior Cervical Fusions, ACS NSQIP: American College of Surgeons National Surgical Quality Improvement Program, CPT: Current Procedural Terminology, LOS: Length of Stay, SSI: Surgical Site Infection Rate, BMI: Body Mass Index, MLSF: Multilevel Spinal Fusion, SPORT: Spine Patient Outcomes Research Trial, IDH: Intervertebral Disc Herniation, SpS: Spinal Stenosis , DS: Degenerative Spondylolisthesis, SF-36: Short Form 36 Outcomes Measure, HTN: Hypertension, CAD: Cardiovascular disease, ST: Stroke, QOL: Quality of Life, MCID: Minimal clinically important differences, SEA: Spinal Epidural Abscesses, MSSA: Methicillin-sensitive *Staphylococcus aureus*, MRSA: Methicillin-resistance *S. aureus*, SEA: Spinal Epidural Abscess, HbA1c: Glycosylated hemoglobin; LMD: lumbar microdiscectomy, ACDF: Anterior cervical decompression and fusion, a LDF: Lumbar decompression and fusion, Fx: Fracture

dependent diabetes (NIDD) vs. non-DM. Others defined newly diagnosed DM, uncontrolled DM (UCDM) vs. controlled DM (CDM). Notably, for those with more severe DM (IDDM), greater morbidity, AE, 30-day readmission/reoperation rates, and poor overall outcomes were observed.

In this study, we queried PubMed utilizing the following search engines; diabetes, spinal surgery, complications/adverse events (AE), outcomes, morbidity, and mortality. The 27 studies identified varied markedly in quality and design, ranging from small series to large national database analyses. In the Browne *et al*. (2007) report, that included an evaluation of 197,461 NIS (Nationwide Inpatient Sample 1988–2003) patients undergoing lumbar spine fusions, there were 11000 (5.6%) diabetics (based on HbA1c testing); the diabetic patients exhibited higher rates of infection, pneumonia, in-hospital mortality, hospital costs, required more transfusions, and had longer lengths of stay (LOS) vs. non-DM patients [Table 1].[2] In Phan *et al*. (2016) using the ACS-NSQUIP database comprising 3726 patients undergoing anterior cervical discectomy/fusion, the 270 patients who were diagnosed as NIDDM had more

Table 2: Increased risks of spine surgery in diabetic patients (references 2014-2015)

Authors year	Number of patients	Operations	Risks factors	Complications	Outcomes
Chikuda[3] 2014	11,005 Japan Cervical Spine Injury Risks Stroke	8,031 M 2,974 F Average 53.5 years old	Fracture (Fx) 2,363 Fx/cord injury 1,283 No Fx/Cord injury 7,359	Ischemic Stroke 115 (1%) LOS 26 days In hospital death 456 (4.1%)	Ischemic Stroke correlated with: Age DM 1st Level of consciousness
Arnold[1] 2014	Mild DM Not a contraindication for cervical spine surgery	236 No DM 42 DM 37 mild 5 moderate)	Outcomes: NDI SF-36 mJOA Score	DM Patients Older <Smokers >SSI/>Disability >Nurick Grades preop/postop	Same 1-2 year outcomes; = Improvement±DM
Patel[17] 2014	128 DM SEA 79 M, 49 F Mean Age 52.9 Mean 241 days Pain 100% Fever 50% Weak 47%	54.7% Lumbar 39.1% Thoracic 35.0% Cervical 23.4% Sacral 3.85%	Ventral 36% Dorsal 41% A/P 23% MSSA 40% MRSA 30%. Risks; IV drugs 39.1% DM 21.9%, None 22.7%	IV Antibiotics: 51 Group I; 41% failed medical Rx/ Late surgery (group 3) Group 2: 77 Surgery/ antibiotics	Predict medical Failure: DM, CRP >115 WBC >12.5 +Blood culture >>Outcomes= Early surgery
Machino[13] 2014	Cervical DD laminoplasty 505 CSM	105 DM 400 No DM=Results	311 males 194 Females Mean age 66.6	DM <Preop JOA and <Postop JOA Recovery rates	DM/No DM=Complications
Guzman[9] 2014	NIS: 3 Groups Uncontrolled (UC) DM Controlled DM No DM	UC DM vs. Non DM: > PE >Infections >Hospital mortality >LOS by 5 days	Controlled DM vs. no DM: > LOS by 1 DAY>Costs	Control DM vs. UC DM: > Outcomes <Costs <AE	> Risks AE (UC) DM vs. Controlled vs. No DM
Nakanishi[15] 2015	DM Negative Impact IONM CCM 22 CCM/DM 92 CCM no DM 24 Controls	PCT=Peripheral Conduction Time, CCT Central motor conduction time	CCM/DM + CCM: MEP PCT, CMCT Significant longer vs. controls	PCT significantly longer CCM-DM vs. CCM No differences MEP and CMCT CCM DM vs. CCM groups	MEP PCT and CMCT showed abnormal in upper and lower motor neurons in DM patients
Wukich[27] 2015	285 million with DM age 20-79 AE >Spine surgery	Poorly controlled DM: negative impact on healing	Worse Outcomes Poorly controlled DM	Well controlled DM=Outcomes to No DM	Recommendation: Make every effort to control DM

IDDM: Insulin dependent diabetes mellitus, NIDDM: Non-insulin dependent diabetes mellitus, ACDF: Anterior cervical discectomy and fusion, IONM: Intraoperative Neural Monitoring, MEP: Motor Evoked Potentials, PCT: Peripheral Conduction Time, CCT: Central motor conduction time, NHIRDT: National Health Insurance Research Database of Taiwan, PCF: Posterior Cervical Fusions, ACS NSQIP: American College of Surgeons National Surgical Quality Improvement Program, CPT: Current Procedural Terminology, LOS: Length of Stay, SSI: Surgical Site Infection Rate, BMI: Body Mass Index, MLSF: Multilevel Spinal Fusion, SPORT: Spine Patient Outcomes Research Trial, IDH: Intervertebral Disc Herniation, SpS: Spinal Stenosis, DS: Degenerative Spondylolisthesis, SF-36: Short Form 36 Outcomes Measure, HTN: Hypertension, CAD: Cardiovascular disease, ST: Stroke, QOL: Quality of Life, MCID: Minimal clinically important differences, SEA: Spinal Epidural Abscesses, MSSA: methicillin-sensitive *Staphylococcus aureus*, MRSA: Methicillin-resistance *S. aureus*, SEA: Spinal Epidural Abscess, HbA1c: Glycosylated hemoglobin, LMD: Lumbar micro discectomy, ACDF: Anterior cervical decompression and fusion, a LDF: Lumbar decompression and fusion, Rx: Treatment, AP: Anterior/posterior (circumferential), UC: Uncontrolled, DD: Double Door, CCM: Compressive Cervical Myelopathy

urinary tract infections and returns to the operating room vs. those without a diagnosis of DM. Furthermore the 171 IDDM required more reoperations, 30-day readmissions, and had longer LOS (by 5 days) compared with non-DM [Table 3].[19] In another ACS-NSQIP study of 5627 patients undergoing posterior cervical fusions, Medvedev *et al.* the authors found that 2029 (36.1%) had AE largely attributed to DM (e.g., more wound complications) and smoking, correlating with higher preoperative American Association of Anesthesia (ASA) scores [Table 3].[14] In a further NSQIP study involving 51277 patients, Qin *et al.* (2016) looked at outcomes for patients with NIDDM, IDDM, or non DM; greater LOS was seen in both diabetic populations, whereas IDDM had higher surgery-related AE and 30 day readmissions rates vs. those without in the study [Table 3].[20] These and multiple other studies largely confirmed DM patients [e.g., IDDM, NIDDM, controlled DM (CDM), and uncontrolled DM (UCDM)] exhibited more perioperative morbidity/AE/complications, longer LOS, higher 30-day readmission/reoperation rates, and in some cases mortality compared with non-DM patients.

DIABETES: A MAJOR COMORBIDITY FOR PATIENTS UNDERGOING SPINAL SURGERY

For patients undergoing spinal surgery, Epstein (2012) noted that diabetes (DM) was associated with a higher

Table 3: Increased risks of spine surgery in diabetic patients: (references 2016–2017)

Authors year	Number of patients	Operations	Risks factors	Complications	Outcomes
Phan[19] 2016	ACDF ACS-NSQIP 3,726 series 270 NIDDM 171 IDDM Non DM	30 Days: Readmissions Reoperations Complications	NIDDM vs. Non DM: > UTI >Return to OR	IDDM vs. Non DM >Reoperations >>Readmission >LOS 5 days	IDDM independent predictors for >30 day readmission
Medvedev[14] 2016	ACS-NSQIP 2011-2012 5627 series 36.1% of 2029 AE Posterior cervical fusions (PCF)	AE: Readmissions >Intubation >Reintubation >Reoperation >Transfusion 1482 26.3%	9.8% AE -transfusions >Intubation >48 h 83 (1.5%) Reintubation 72 (1.3%) Readmission 398 (7.8%)	Reoperation 273 (4.9%) for infection >AE Risks: Females >OR Time AP surgery In patient preop	>AE Risks: DM Smoking ASA classification 3 or >
Pease[18] 2016	4489 IONM Spine OR PCF/PLF 3 years; DM, New deficits	PCF 1373 98 (7.1%) SEP abnormal. 13/98 (13.2%) New Deficit	PCF No Changes 49 (3.8%) new deficit	SEP EMG PLF: 2410 249 (10.2%) Changes 8 (3.2%) New deficits	3 (1.7%) No changes New Deficit
Shin[21] 2016	Glycemic control adult	Idiopathic Scoliosis/ Fusions	NIS 200-2011 Over 45 years old	Controlled DM vs. No DM >Risk ARF with fusions	UCDM >risk Postop bleeding ARF, DVT In Patient Mortality
Chiu[4] 2016	NHIRDT 6949 vs. controls	Variables DM HTN Osteoporosis CVA	Instrumented fusions; > risks VCF Female	Instrumented fusions; > risks Elderly Osteoporotic	Instrumented fusions; > risks Males Instrumented fusions
Kerr[10] 2016	Orthopedics Hip, Spine Knee surgery 318,861	DM vs. Non DM Impact on LOS	Total of 11,476,073 Patients 309 Hospitals	16% Patients had DM Mean LOS 3.11 days no DM 3.4 days DM	No Significant difference with/without DM On LOS
Lee[11] Spine 2016	Resident Impact on PCF	ACS NSQIP Database 2005-2012 448 Cases Residents 224 (43.1%)	Residents >Transfusions >LOS >5 days >OR time >4 hours	Residents: No >mortality Minimal impact on morbidity	Higher LOS with/without Residents: Age >/= 81, Diabetes
O'Neill[16] 2011	SSI Rate in for Spine Fusions 110 Patients 2 Years	Apply Vancomycin Powder to < SSI in Diabetes having spinal fusions	54 Control Group IV Antibiotics 13% SSI in control group	56 Experimental Group: IV + Local Antibiotics 0% SSI in treatment groups No complications	Same comorbidities; Prior surgery, DM >BMI, Deficits OR time, EBL Level of injury
Gaviola[8] 2016	Topical Vanco Multilevel Spine Fusions 2010-2014	SSI: IV Cefazolin + Topical Vanco Vs. IV Cefazolin alone	326 Patients 29 (8.9%) SSI	Trend <SSI with Topical Vanco + IV cefazolin Not significant	SSI 6/116 (5.2%) Treatment vs. SSI 23/210 (11%) controls >Risks SSI; F Both Groups
Silverstein[22] 2016	QOL and MCID	2008-2014 6 Months 212 Patients	Non DM Significantly > Outcomes EQ-5D, PDQ PHQ-9	DM no significant improvementEQ-5D, PDQ PHQ-9	DM and Kidney disease both predictors poorer outcomes EQ-5D
Qin[20] 2016	NSQUIP 51,277 patients 2005-2013 Lumbar Spine Surgery	No DM NIDDM IDDM	>LOS DM: No DM 2.6 days NIDDM 3.2 days	>LOS DM: IDDM 3.9 days All DM >AE	IDDM >Surgical AE >30-day Readmissions

Contd...

Table 3: Contd...

Authors year	Number of patients	Operations	Risks factors	Complications	Outcomes
Liu[12] 2017	DM CSM Meta-analysis 38,680	6 Studies With DM No DM	DM >Risks: Infections Hematomas Cardiac events	DM No differences; CSF leaks C5 palsy	Better controlled DM leads to better outcomes

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risk of infection, osteoporosis, and pseudarthrosis, as well as other major medical risk factors.[6] The mortality rates for patients undergoing spine surgery (with or without DM) within six months of having an acute myocardial infarction was 40%. For DM or non DM patients who had a coated stent placed within the last year (e.g. for cardiac, carotid or peripheral vascular disease), anti-platelet therapy could not be stopped; early cessation of this medication could result in acute graft occlusion/death. Diabetes was also highly correlated with other major comorbidities including; obesity/morbid obesity, chronic obstructive pulmonary disease (COPD), perioperative deep venous thrombosis (DVT), and pulmonary embolism (PE).

VARIABLE IMPACT OF DIABETES ON CERVICAL SPINE SURGERY

Although one study documented the absence of a negative impact of DM on AE events associated with decompressive cervical spine surgery, three studies did show increased DM-related perioperative morbidity. In the first study, Arnold *et al.* (2014), evaluated 42 DM (37 mild/5 moderate) vs. 236 non DM: they found that DM had no negative impact on the results of decompressive cervical surgery for cervical spondylotic myelopathy (CSM) [Table 2].[1] Patients in both groups showed similar Neck Disability Index (NDI), Short Form-36 Health Surveys [(2 Health Scales; SF-36v2), modified JOA Scores (mJOA), Nurick Grades], and 1–2 year surgical complications and improvement rates. Three other studies, however, demonstrated the negative impact of DM on cervical spine surgery, likely attributed to their larger sampling sizes [Tables 2 and 3].[3,9,12] Utilizing the Nationwide Inpatient Sample (2002–2011), Guzman (2014) *et al.* found an increased risk/complication/AE rate for uncontrolled DM (UCDM)/controlled DM (CDM) vs. non-DM undergoing comparable cervical spine operations [Table 2].[9] UCDM patients showed statistically significantly increased respiratory, cardiac, and genitourinary complications, more frequent PE, postoperative infections, in-patient mortality, and increased mean LOS (by almost 5 days) vs. non-DM patients. CDM patients also had increased perioperative AE rates, and increased costs, but less than that for UCDM patients; of interest, however, their mean LOS was only increased by one day vs. non DM patients. Chikuda *et al.* (2014) evaluated 11005 patients following cervical spine injuries and documented a 1% (115 patients/over 26 day LOS) incidence of ischemic stroke. These patients demonstrated an increased frequency of DM along with more advanced age [Table 2].[3] When Liu *et al.* (2017) evaluated 38680 patients from 6 studies undergoing cervical spine surgery for CSM, patients with DM exhibited more wound infections, epidural/wound hematomas, chronic lung disease, and cardiac complications vs. non DM patients [Table 3].[12] They strongly recommended better control of diabetes prior to cervical spinal surgery (e.g., more screened with preoperative HbA1c levels) to reduce AE, and strongly recommended DM patients be followed with more stringent diabetic/insulin-based protocols postoperatively to improve outcomes.

NEGATIVE IMPACT OF DIABETES ON ANTERIOR CERVICAL DISKECTOMY/FUSION

Out of 3726 patients undergoing ACDF obtained from an ACS NSQIP (American College of Surgeons-National Surgical Quality Improvement Program) database, Phan *et al.* (2016) showed that IDDM (171 patients) and NIDDM (270 patients) exhibited higher risks, complication rates, AE, and greater 30-day reoperation/readmission rates [Table 3].[19] Compared with those who did not have DM, IDDM had higher reoperation/readmission rates, and longer average LOS (mean >5 days), whereas NIDDM experienced more urinary tract infections (UTI) and returns to the operating room (OR).

VARIABLE IMPACT OF DIABETES ON POSTERIOR CERVICAL SURGERY

DM had a variable impact on the frequency of AE and outcomes doe for posterior cervical surgery [e.g., including laminoplasty and posterior cervical fusion (PCF)]. Over 12 months following double door laminoplasty performed for CSM (mean 66.6 years of age), Machino (2014) showed comparable AE/outcomes for 105 DM vs. 400 non DM patients [Table 2].[13] Alternatively, in Medvedev *et al*. (2016) analysis of the ACS-NSQIP database (2011–2012) for 5627 patients undergoing posterior cervical fusion revealed 26.3% (1482 patients) of AE were related to transfusions whereas diabetes largely contributed to the remaining 9.8% of AE. Other risk factors included; prolonged intubation (>1.5%), reintubation in 72 (1.3%), readmission in 398 (7.8%) patients, and reoperations (4.9%) in 273 patients (e.g. most for infections) [Table 3].[14] Additional risk factors included; female sex, longer surgical time, combined anterior-posterior surgery, preoperative inpatient status, smoking, ASA class 3 or higher, and older age. Lee *et al*. (2016) additionally showed that residents performing 223 (43.1%) of 448 PCF posterior cervical fusions (PCF: ACS NSQIP database (2005–2012) increased transfusion rates, LOS (by >5 days), and OR times (>4 hours) [Table 3].[11] Interestingly, DM, age ≥81, and multilevel fusions were independent risk factors increasing complication rates with/without resident involvement.

DIABETES NEGATIVE IMPACT ON INTRAOPERATIVE NEURAL MONITORING FOR SPINE SURGERY

DM had a negative impact on intraoperative neural monitoring (IONM) for patients undergoing decompressive cervical surgery for myelopathy (CCM) [Tables 2 and 3].[15,18] Nakanishi *et al*. (2015) compared the results of IONM for 22 patients with CCM/DM vs. 92 with CCM/no DM vs. 24 controls/no DM undergoing decompressive cervical surgery [Table 2].[15] Correlating JOA scores 1 year postoperatively with intraoperative Motor Evoked Potentials (MEPs), Peripheral conduction time (PCT), and Central Motor Conduction Times (CMCT) all potentials were abnormal for DM in both the upper and lower motor neurons. Pease *et al*. (2016) also found DM was one of the several variables contributing to significant IONM changes (e.g., sensitivity/specificity of IONM in detecting new neurological deficits) during 1373 posterior cervical procedures [Table 3].[18] Other variables included; length of surgery, age, sex, BMI (body mass index), hypertension (HTN), coronary artery disease (CAD), cerebrovascular disease, and smoking.

DIABETES: VARIABLE IMPACT ON ADVERSE EVENTS/LENGTH OF STAY FOR ELECTIVE GENERAL ORTHOPEDIC PROCEDURES

Two studies demonstrated the variable impact of DM on AE/LOS/outcomes for general orthopedic procedures [Tables 2 and 3].[10,27] Kerr *et al*. (2016) found 1 of 3 hospitalized adults in California (CA) had DM; this did not significantly increase LOS for elective general orthopedic surgery [Table 3].[10] Of 11,476,073 discharges from 309 CA hospitals, DM did not significantly increase LOS following hip, spine, or knee surgery ($n = 318,861$ patients). The Public Use California Patient Discharge Data Files (CPDDF) (2010-2012) showed 16% of discharges included a diagnosis of diabetes; however, the average LOS was comparable with (3.40 days with DM) vs. without DM (3.11 days without DM). Alternatively, Wukich (2015) observed, following orthopedic spine surgery, that poorly controlled DM resulted in poorer wound healing, and higher rates of AE, neuropathy, peripheral artery disease, and end-stage renal disease [Table 2].[27]

The marked disparity in results for orthopedic procedures involving DM patients utilizing such large database analyses remains difficult to explain. One question is who was doing the surgery? When residents were involved, greater morbidity typically follows (e.g., greater LOS and more transfusions), a finding typically attributed to their inexpert technical/surgical skills. Here, better supervision by more senior surgeons/physicians may improve results. On the other hand, there may be great disparities in different settings (e.g., private practice vs. academia with residents) regarding how patients are selected for surgery. Some surgeons may choose to operate on patients irrespective of their comorbidities, whereas others may perform surgery without sufficient indications (e.g., unnecessary surgery). Another major consideration is whether the data entered into the various large databases (ACS-NSQIP, CPDDF, NIS) were correct, relevant, and appropriate for the problem under investigation. Certainly, these questionnaires may miss the critical factors that may be truly impacting outcomes.

DIABETES RESULTED IN GREATER MORBIDITY/MORTALITY AND POORER OUTCOMES WITH LUMBAR FUSIONS VS. THOSE WITHOUT DIABETES MELLITUS

Multiple studies documented increased complication/AE rates for DM patients undergoing lumbar fusions [Tables 1-3].[2,4,7,20,22,23] Browne *et al*. (2007) used the NIS database (1988–2003) to study perioperative morbidity and mortality rates for 197,461 patients undergoing lumbar fusions; 11000 patients (5.6%) had a postoperative diagnosis of DM (using HbA1c levels) that increased the

risk for postoperative infection, transfusions, pneumonia, in-hospital mortality, non-routine discharges, higher total charges, and LOS. [Table 1].[2] Freedman *et al*. (2011) in the Spine Patient Outcomes Research Trial (SPORT) found DM (199 patients) had better outcomes (SF-36, ODI) without LDH surgery [Table 1].[7] DM were also older, had higher BMIs, and greater frequencies of hypertension, stroke, cardiovascular disease, and joint pathology. In Takahashi *et al*. (2013) series, poor outcomes followed lumbar fusions in DM (41 patients; lower17.9 VAS score) vs. non-DM (124 patients; higher VAS scores 29.3) patients 50 years of age or older [Table 1].[23] DM also correlated with higher rates of pseudarthrosis (20% with DM vs. 3% without DM), and residual postoperative back pain. In addition, using the National Health Insurance Research Database of Taiwan involving 6949 patients undergoing instrumented spinal fusion. Chiu *et al*. (2016) found DM had higher frequencies of delayed postoperative vertebral compression fractures (VCFs) [Table 3].[4] When Qin *et al*. (2016) studied the NSQIP database of 51277 patients undergoing lumbar surgery, LOS was significantly increased for NIDDM (3.2 days) and IDDM (3.9 days) who also had more medical complications vs. non DM (2.6 days) [Table 3].[20] Notably, IDDM also exhibited greater surgical complications and higher 30-day unplanned readmission rates. Silverstein *et al*. (2016) looked at the impact of DM (212 patients) vs. no DM on patients undergoing lumbar decompressions; non DM showed significant improvements in EQ-5D (EuroQol five dimensions questionnaire), PDQ (Parkinson's disease Questionnaire), and PHQ-9 (Patient Health Questionnaire-9), as well as on postoperative quality of life (QOL) questionnaires utilizing minimal clinically important differences (MCIDs) [Table 3].[22] It would certainly appear that larger the study, the more clearly the negative impact of DM for patients undergoing for patients undergoing spinal surgery.

VARIABLE IMPACT OF DIABETES ON SCOLIOSIS FUSION SURGERY

Two series, one very small, and another every large (NIS), demonstrated very different conclusions regarding the impact of DM vs. no DM on scoliosis surgery [Tables 1 and 3].[5,21] Cho *et al*. (2012) found comparable major/minor complications/outcomes for scoliosis surgery performed in their very small series involving just 23 NIDDM vs. 23 controls (non-DM) over a minimum 2-year period [Table 1].[5] Alternatively, Shin *et al*. (2016) large NIS database (2002–2011) series focusing on non DM, CDM, and UCDM patients undergoing fusions for idiopathic scoliosis (>45 years of age), documented poor glycemic control in DM had a major negative impact on morbidity/mortality rates [Table 3].[21] Furthermore, CDM patients exhibited significantly higher rates of acute renal failure (ARF), whereas UCDM patients had more acute postoperative hemorrhages, deep vein thrombosis, and in-patient mortality. Here, the Shin *et al*. study's much larger patient sample allowed for documentation of significantly greater morbidity for DM vs. non DM patients undergoing spinal surgery.

DIABETES: A MAJOR RISK FACTOR FOR SPINAL EPIDURAL ABSCESS (SEA)

DM is a major risk factor for patients to develop SEA following spinal surgery, it could also contribute to the postoperative risk of SEA. When Patel *et al*. (2014) examined 128 consecutive bacterial SEA extending over an average of 3.85 disc levels, DM was a major risk factor (21.9%) along with intravenous (IV) drug abuse (39.1%) [Table 2].[17] Thirty of 51 patients were successfully treated with antibiotics alone (group 1), whereas 21 (41%; group 3) failed medical management and warranted delayed surgery. Factors contributing to failure of antibiotics alone to treat seA included; DM, C-reactive protein >115, white blood count >12.5, and positive blood cultures. The remaining 77 group 2 patients were successfully initially managed with surgery, followed by IV antibiotic therapy.

VANCOMYCIN POWDER WITH ROUTINE INTRAVENOUS ANTIBIOTICS DECREASED THE RISK OF SURGICAL SITE INFECTION FOLLOWING INSTRUMENTED FUSION

Ten percent of patients undergoing posterior spinal instrumented infections secondary to trauma typically develop surgical site infection (SSI: deep or superficial) (deep/superficial) [Table 1].[16] Over a 2-year period, O'Neill *et al*. (2011) observed a reduced 0% incidence of SSI for 56 patients undergoing instrumented posterior spine fusions who had received local vancomycin powder/IV antibiotics (cefazolin) vs. a 13% frequency of SSI for 54 control patients receiving IV cefazolin alone [Table 1].[16] However, in Gaviola *et al*. series (2016), they documented only a "trend" favoring the reduction of SSI following multilevel spinal fusions (MLSF) using Vancomycin powder; SSI occurred in 5.2% (6/116 patients) utilizing topical Vancomycin/IV cefazolin vs. 11% (23/210 patients) receiving cefazolin alone [Table 3].[8] Major risk factors contributing to the risk for SSI notably included DM along with female sex, and greater invasiveness.

DIABETES ALONE OR WITH OTHER MAJOR COMORBIDITIES INCREASED TOTAL HOSPITAL COSTS AND LENGTH OF STAY FOR SPINE SURGERY

For patients undergoing spine surgery, DM alone or combined with other major comorbidities, including

hypothyroidism, elevated BMI, older age, and depression, increased total hospital costs, and LOS. When Walid *et al*. (2010) tested elevated glycosylated hemoglobin levels (HbA1c) >/=6.1) for patients undergoing lumbar microdiskectomy (LMD), ACDF, or lumbar decompression/fusion (LDF), they discovered 13.3% were known DM, 14.3% were unknown DM (e.g., prior to surgery), and 72.4% had no DM [Table 1].[24] Notably, the unknown DM undergoing LDF demonstrated significantly higher costs and LOS vs. non DM, prompting the authors to subsequently perform routine preoperative screening for DM with HbA1c levels. Evaluation of patients undergoing LMD (*N* = 237), ACDF (*N* = 339), and LDF (*N* = 211), revealed that 32.5% of 643 patients had elevated HbA1c levels (≥6.1%=DM); an additional 4.3% had both DM and hypothyroidism [Table 1].[25] LDF patients with both DM/hypothyroidism exhibited the longest LOS (8 days), and highest hospital costs ($71352). Subsequent evaluation of (2011) 816 patients (2005 and 2008) undergoing LMD (20.5%), ACDF (60.3%), and LDF (19.2%) revealed increased costs due not only to DM but also to elevated BMI and older age [Table 1].[26] For females undergoing ACDF, DM and severe obesity alone significantly increased the average charge to $34943 vs. $25633. For females undergoing LDF, costs were also significantly higher for those with both DM and depression ($65782) vs. DM alone ($53504). The economics of spine surgery indicate that DM either alone or combined with other major risk factors significantly contributed to more prolonged LOS and higher hospital costs. Screening for DM prior to surgery with routine HbA1c levels may better prepare the surgeon, patient, and hospital for increased perioperative challenges.[24]

CONCLUSION

The vast majority of the larger series utilizing major U.S. patient databases, documented that diabetic patients (e.g., IDDM, NIDDM, CDM, UCDM) undergoing spine surgery exhibited more perioperative morbidity/AE/complications, longer LOS, higher 30-day readmission/reoperation rates, and increased mortality compared with non DM. Only a subset of smaller studies, too small to yield "significant findings," demonstrated no negative impact of DM on the results of spinal surgery. Future routine preoperative screening for DM with HbA1c levels would likely be worthwhile (e.g., one series demonstrated 14.3% of patients were "unknown DM"), as this could facilitate better preoperative, intraoperative, and postoperative management.[24]

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