

Prevalence of Previously Unknown Elevation of Glycosylated Hemoglobin in Spine Surgery Patients and Impact on Length of Stay and Total Cost

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BACKGROUND: Elevated levels of glycosylated hemoglobin (HbA1c) among spine surgery patients may have an impact on length of stay (LOS) and healthcare cost.

MATERIALS AND METHODS: We retrospectively reviewed the charts of 556 spine surgery patients who underwent 1 of 3 types of surgery: lumbar microdiscectomy (LMD), anterior cervical decompression and fusion (ACDF), and lumbar decompression and fusion (LDF). Information was collected about their diabetes mellitus (DM) history and HbA1c levels. We used HbA1c 6.1% as the screening cutpoint. Percentages of nondiabetic patients, those with subclinical elevation of HbA1c and those with already known DM were calculated and statistical analysis was applied.

RESULTS: After excluding the small group of well-controlled DM ($n = 14$), 72.4% of patients were nondiabetic, 14.3% were subclinical patients with previously unknown HbA1c elevation, and 13.3% were already known, confirmed DM patients. There were significant differences in the LDF group between the “No DM” and “Subclinical” groups ($P < 0.05$) in terms of cost and LOS ($P < 0.05$). Age and body mass index (BMI) were very significant predictors of total cost in spine surgery patients ($P \leq 0.001$), in addition to the type of surgery. Univariate analysis with age, BMI, or both as covariates deprived DM-HbA1c status of statistical significance ($P > 0.05$) in determining cost.

CONCLUSIONS: There is a significant segment of spine surgery patients who were unaware of their elevated HbA1c status before their preoperative visit. These patients seem to utilize more healthcare resources, which is especially evident in the LDF group. We believe that HbA1c should be considered in the routine preoperative workup of spine surgery patients.

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KEYWORDS: age, body mass index, cost, diabetes mellitus, length of stay, spine surgery.

Diabetes mellitus (DM) is a common chronic disease with a long downward course and serious systemic consequences. The percentage of the population with diagnosed diabetes continues to rise. In 2007, more than 246 million people had diabetes worldwide.¹ In the United States, the diabetes rate was 5.8% in 2007, and is estimated to rise to 12% by 2050.^{2,3} Many factors may contribute to this rise in the prevalence of diabetes, including higher prevalence of overweight and obesity, unhealthy diet, sedentary lifestyle, changes in diagnostic criteria, improved detection methods, decreasing mortality, a growing elderly population, and growth in minority populations with predisposition to diabetes; (ie, African Americans, Hispanics, and Native Americans).^{1,4,5} This is consistent with the “thrifty genotype” hypothesis, which explains the morbid prevalence of obesity, diabetes, and atherosclerosis-related complications in modern times.⁶

The total estimated cost of diabetes in 2007 was \$174 billion, including \$116 billion in excess medical expenditures (\$27 billion for direct diabetes care, \$58 billion for treatment

of diabetes-related chronic complications, and \$31 billion in excess general medical costs) and \$58 billion in reduced national productivity.⁷ The largest component of medical expenditures that is attributed to diabetes has been hospital inpatient care (50% of total cost).⁸

Spine surgery is expensive and any factor that influences cost of surgery merits meticulous study, especially with the financial difficulties that the healthcare system is facing. Diabetic patients are known to be more vulnerable to postoperative complications such as fever, wound infection, foot drop, and nonunion than their nondiabetic peers.^{9–13} In diabetic spine surgery patients, a negative correlation was reported between the recovery rate and the preoperative glycosylated hemoglobin (HbA1c) level.¹⁴ However, the potential impact of undiagnosed diabetes on these variables have not yet been extensively studied. In order to determine the prevalence of explicit DM and undiagnosed elevation of HbA1c among spine surgery patients and its impact on healthcare cost, we conducted the following study.

Patients and Methods

We retrospectively reviewed the charts of 556 spine surgery patients who were operated on between 2005 and 2007 and had 1 of 3 types of surgery: lumbar microdiscectomy (LMD), anterior cervical decompression and fusion (ACDF), and lumbar decompression and fusion (LDF). Information was collected about their diabetes history, HbA1c level, age, race, body mass index (BMI), comorbidities, length of stay (LOS), and total cost (hospital and physician). Due to the high percentage of glucose metabolism disturbance in the population and the many reports of increased postoperative complications related to diabetes, patients are routinely seen by an internist on the preoperative visit and they undergo electrocardiography and laboratory testing, including HbA1c. Hence HbA1c was recorded for 456 patients. We used 6.1% as a screening cutpoint for high HbA1c and classified patients to 4 groups according to their DM-HbA1c status:¹⁵

1. Those with history of DM and HbA1c \geq 6.1% (DM);
2. Those without history of DM and HbA1c \geq 6.1% (subclinical HbA1c elevation);
3. Those with history of DM and HbA1c $<$ 6.1% (well-controlled DM);
4. Those without history of DM and HbA1c $<$ 6.1% (no DM).

The second group was our main group of interest (subclinical, previously unknown HbA1c elevation). The third group (patients with well-controlled DM, which is uncommon) was excluded ($n = 14$). To prevent confusion in the coming text, mentioning “elevation of HbA1c” will imply the second group, while the term “diabetes” will refer to the first group.

We calculated the percentages of nondiabetic patients, those with subclinical HbA1c elevation, and those with already known DM. We computed the mean (m) and standard deviation (SD) for cost, age, and BMI. Using SPSS v.16 (SPSS, Chicago, IL) we applied the analysis of covariance (ANCOVA) to determine the impact of DM-HbA1c on total healthcare cost after controlling for type of surgery. We used analysis of variance (ANOVA) and post hoc Scheffe test to check for any significant differences in healthcare cost (hospital and surgery costs), age, gender, race, and BMI between the three DM-HbA1c groups. Finally, we applied regression analysis to figure out significant factors/predictors of total cost in spine surgery patients beside type of surgery.

Results

After excluding the third group, we had 442 spine surgery patients, 26.7% LMD, 49.1% ACDF, and 24.2% LDF. They were 21–92 years of age (over 60 years old = 41%), and nearly equally divided according to gender (48.2% males). They were mostly Caucasian (78.3% Caucasians and 21% African Americans). There were no Hispanics in the sample,

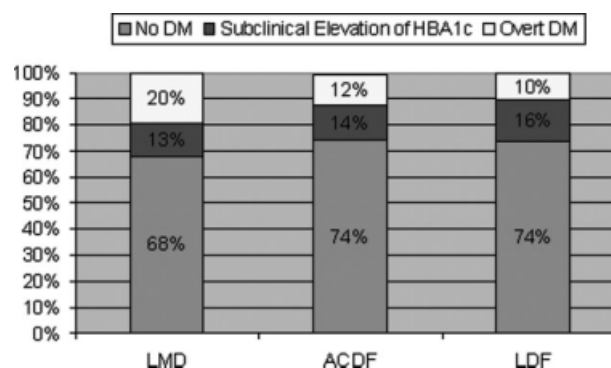


FIGURE 1. DM-HbA1c subgroups in spine surgery patients.

which may be due to the small proportion of the Latino population living in Macon, GA.

Calculations showed that 72.4% of the above patients were nondiabetic, 14.3% were subclinical patients with elevated HbA1c, and 13.3% were already known, confirmed DM patients. Results showed that elevation of HbA1c was highest and diabetes was lowest in the LDF group, 16% and 10%, respectively. On the contrary, elevation of HbA1c was lowest and diabetes was highest in the LMD group, 13% and 20%, respectively (Figure 1).

While analyzing the data, we took into consideration that the main cost-determining factor was type of surgery ($P < 0.001$), so the pure impact of the DM-HbA1c status on total cost was elicited by using ANCOVA and including type of surgery as a covariate. Table 1 shows the total cost for spine surgery patients per type of surgery and DM-HbA1c status.

As evident in Table 1 and confirmed by statistical analysis, DM-HbA1c status was a very significant determinant ($P < 0.01$) of total cost. We performed ANOVA in each surgical category to determine the significance of differences in total cost between DM-HbA1c status groups. There were significant differences in the LDF group between the “no DM” and “subclinical” groups ($P < 0.05$) in terms of cost and LOS, and in the ACDF group between patients without DM and those with already known DM in cost ($P < 0.05$). Figures 2 and 3 summarize the results mentioned above.

As expected, age ($P < 0.001$) and BMI ($P \leq 0.01$) were significantly different between DM-HbA1c groups. Scheffe test showed significant difference between no DM and DM ($P < 0.001$) groups and between subclinical and DM groups ($P < 0.01$) regarding age and between no DM and DM groups ($P < 0.05$) regarding BMI. There was no difference ($P > 0.05$) between the three DM-HbA1c groups regarding type of surgery. The subclinical patients with HbA1c elevation appeared to be as old as nondiabetic patients ($P = 0.669$) but as heavy as diabetic patients ($P = 1.000$).

The range of BMI in the sample was 17 to 52 with 36% over 30; (ie, obese) (Table 2). Regression analysis showed that type of surgery, age, and BMI were very significant predictors of total cost in spine surgery patients ($P \leq 0.001$). In

TABLE 1. Length of Stay and Total Cost Per Type of Surgery and DM-HbA1c Status

	LMD			ACDF			LDF		
	No DM	HbA1c	DM	No DM	HbA1c	DM	No DM	HbA1c	DM
LOS (days)	2.75 ± 4.318	2.48 ± 2.926	2.48 ± 1.904	1.42 ± 1.984	1.43 ± 1.165	2.52 ± 3.991	4.68 ± 2.509	6.96 ± 5.897	5.55 ± 3.616
Cost (dollars)	23115 ± 14608	22306 ± 7702	23644 ± 7068	28363 ± 7673	29420 ± 6130	36748 ± 31970	54914 ± 14034	65974 ± 18341	61536 ± 14527

NOTE: Values are given as mean ± SD.

Abbreviations: ACDF, anterior cervical decompression and fusion; DM, already known diabetes; HbA1c, undiagnosed elevation of glycosylated hemoglobin without history of diabetes; LDF, lumbar decompression and fusion; LMD, lumbar microdiscectomy; LOS, length of stay; No DM, no diabetes.

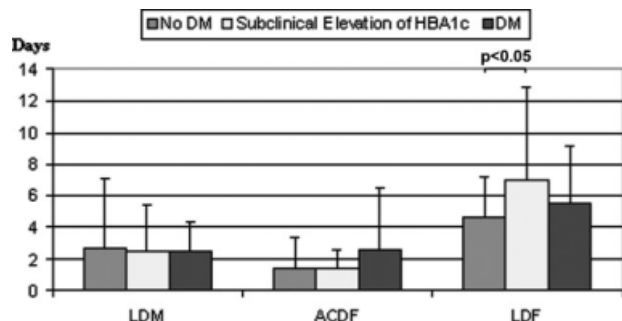


FIGURE 2. LOS in days (mean ± SD) per surgery type and DM-HbA1c status.

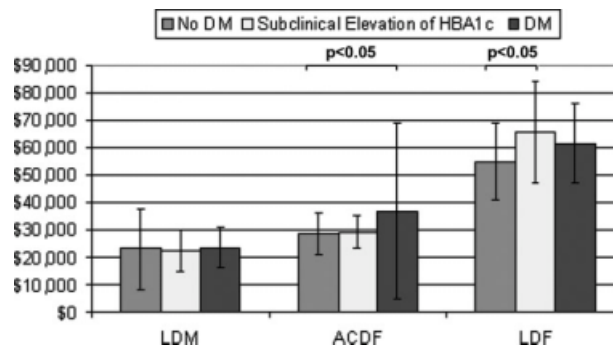


FIGURE 3. Total cost in dollars (mean ± SD) per surgery type and DM-HbA1c status.

our study, total cost was not dependent on sex or race. Repeating analysis with age, BMI, or both as covariates (ANCOVA) deprives DM-HbA1c status of statistical significance ($P > 0.05$).

Concerning comorbidities that could affect HbA1c level, only 1.4% of patients had a history of advanced or chronic renal disease and none had hemoglobinopathy.

Discussion

According to the Centers for Disease Control and Prevention (CDC), approximately 54 million people in the United States have prediabetes and nearly 21 million have diabetes.³ This places almost 25% of the population at risk for diabetic complications. Prediabetes is a term used to distinguish people who are at increased risk of developing diabetes. People with prediabetes have impaired fasting glucose (100–125 mg/dL), impaired glucose tolerance (140–199 mg/dL at 2 hours), or both.¹⁶ The actual national burden of diabetes most likely exceeds the \$174 billion estimate because of excess medical costs associated with prediabetic patients.

Due to the impracticality of the 2 tests mentioned above as screening methods for diabetes and prediabetes, we used HbA1c to screen for glucose metabolism disturbance. This marker does not need overnight fasting or a 2-hour glucose loading test. The HbA1c level gives an average of glycemic control over the previous 120 days, as red blood cells have a lifespan of 120 days. Although the use of HbA1c for the di-

agnosis of diabetes is not yet established, its availability at the time when the patient is seen (point-of-care testing) is a great advantage over fasting glucose and glucose tolerance tests.^{17,18} The normal range for a person without diabetes is 4.3% to 5.9%.¹⁹ For most people with diabetes the American Diabetes Association recommends targeting an HbA1c of 7% or less. If HbA1c is 8% or higher, it means that the patient's blood glucose is not well-controlled and he/she is at increased risk for developing diabetic complications. In this case, the patient needs modifications in his/her diet, physical activity, oral hypoglycemic medications, or insulin. It is uncommon to have patients with a history of diabetes and HbA1c < 6.1%. Our patient sample confirms this fact ($n = 14$). Therefore, it was not included in the statistical analysis.

The cutpoint 6.1% (2 SD above the mean) was the recommended cutoff point for HbA1c in most reviewed studies.^{15,20} At the Diabetes Control and Complications Trial and Prospective Diabetes Study, the sensitivity of this cutpoint in detecting diabetes was 78% to 81% and specificity was 79% to 84%.¹⁵ HbA1c was shown to have less intraindividual variation and better predicts both microvascular and macrovascular complications.¹⁵ Although the current cost of HbA1c is higher than fasting plasma glucose, its feasibility as a screening tool for DM and as a predictor of its costly preventable complications may make it a cost-effective choice.

TABLE 2. Age and BMI Per Type of Surgery and DM-HbA1c Status

	LMD			ACDF			LDF		
	No DM	HbA1c	DM	No DM	HbA1c	DM	No DM	HbA1c	DM
Age (years)	60 ± 14	59 ± 11	69 ± 9	52 ± 10	58 ± 9	60 ± 10	55 ± 13	54 ± 10	59 ± 7
BMI (kg/m ²)	30 ± 7	33 ± 7	30 ± 6	29 ± 5	31 ± 5	32 ± 5	30 ± 6	33 ± 9	36 ± 9

NOTE: Values are given as mean ± SD.

Abbreviations: ACDF, anterior cervical decompression and fusion; BMI, body mass index; DM, already known diabetes; HbA1c, undiagnosed elevation of glycosylated hemoglobin without history of diabetes; LDF, lumbar decompression and fusion; LMD, lumbar microdiscectomy; No DM, no diabetes.

Unrecognized glycometabolic disturbance as measured by HbA1c have recently been associated with poor outcomes, for example, after acute myocardial infarction.²¹ Postoperative complications in diabetic patients have been attributed to impairments in the immune system and microangiopathy. Patients with poorly regulated glucose levels are at an increased risk for developing infections. Once a person with diabetes has developed an infection, the body is less capable of fighting it off because high glucose levels interfere with the normal function of white blood cells. Moreover, dysfunction in the immune system impairs the inflammatory reaction in local tissues, which is further aggravated by the reduced blood supply due to diabetic microangiopathy. This results in considerable increase in the risk of soft-tissue complications and significant delays in wound and bone healing.²²

Our patient sample was classified according to chart and laboratory findings. The two criteria we used to classify them were a history of diabetes and HbA1c level $\geq 6.1\%$. Results show that patients unaware about their elevated HbA1c level are almost equal to the percentage of patients with history of diabetes. Combined, they make slightly more than 25% of spine surgery patients. These results are consistent with the CDC's estimate of the percentage of diabetes and prediabetes in the general population.³ Further analysis shows that age and BMI are significantly different between DM-HbA1c groups, which is unsurprising since the correlation of diabetes with age and BMI is well-established.²³ Interestingly, the subclinical patients with elevated HbA1c appear to be as old as nondiabetic patients but as heavy as their diabetic peers. This is a remarkable finding that reflects the transitional status of these patients between non-diabetes and diabetes. In addition, age and BMI were found to be very significant determinants of total cost in spine surgery patients. Actually, they were the reasons behind the statistical significance shown by the DM-HbA1c status regarding cost as exposed by the ANCOVA.

This middle category of spine surgery patients with subclinical glucose metabolism disturbance seems to have important economic implications in terms of LOS and total cost in the LDF group. This may be due to the larger share of this middle subgroup in the LDF group of patients, as shown above. Besides, LDF patients stay longer and cost more than other spine surgery patients and consequently

statistical differences between DM-HbA1c subgroups are more evident. LDF is major surgery, with extensive dissection, greater blood loss, and longer operative time than other types of spine surgery and the patients are older and sicker. That may be why there was a more pronounced difference in LOS and cost between its 3 subgroups.

Overall, this work expands upon our understanding of the importance of diabetes and undiagnosed elevation of HbA1c in affecting cost following surgery. However, the study has several limitations that should be taken into consideration. Potential underreporting of diabetes in the patient's chart could skew the results, although this was unlikely due to the repetitive interview of patients on multiple occasions. In addition, HbA1c level could be affected by prescribed medications, which were not included in our inquiries. LOS and cost could also be influenced by non-diabetes-related factors that were not considered in the study. Finally, a bigger sample would have given more power to the results, although 556 patients is, without a doubt, not a small group.

Conclusions

There is a significant segment of spine surgery patients who learn of their disturbed glucose metabolism status for the first time on their preoperative visit. These patients require further investigation, with a fasting glucose test to confirm their diabetes status, and they need to start treatment early to prevent future complications.

HbA1c testing should be considered in the routine preoperative workup of spine surgery patients. This is a simple point-of-care test and its results can be obtained without delay. This will help improve early diagnosis of prediabetes and diabetes and may prevent the onset of type 2 diabetes, thus improving the patient's health and final outcome.

We need continuing research into the healthcare costs of diabetic patients in different medical specialties, as this will improve awareness about the economic impact and cost-effectiveness issues related to this prevalent disease.

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