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The Inherent Value of Preoperative Optimization—Absolute and Incremental Reduction in Components of Metabolic Syndrome Can Enhance Recovery and Minimize Perioperative Burden

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ABSTRACT

Background: Metabolic syndrome (MetS) is an amalgamation of medical disorders that ultimately increase patient complications. Factors such as obesity, hypertension, dyslipidemia, and diabetes are associated with this disease complex.

Objective: To assess the incremental value of improving MetS in relation to clinical outcomes.

Study Design: Retrospective cohort study.

Methods: Patients undergoing elective spine surgery were isolated and separated into 2 groups: MetS patients (>2 metabolic variables: hypertension, diabetes, obesity, and triglycerides) and nonmetabolic patients (<2 metabolic variables). *T* tests and χ^2 tests compared differences in patient demographics. Resolution of metabolic factors was incrementally analyzed for their effect on perioperative complications through utilization of logistic regressions.

Results: A total of 2,855,517 elective spine patients were included. Of them, 20.1% had MeTS (81.4% two factors, 18.4% three factors, 0.2% four factors). MetS patients were older, less female, and more comorbid ($P < 0.001$). About 28.8% MetS patients developed more complications such as anemia (9.8% vs 5.9%), device related (3.5% vs 2.9%), neurologic (2.3% vs 1.4%), and bowel issues (9.7% vs 6.8 %; $P < 0.05$). Controlling for age and procedure invasiveness, having 3 MetS factors increased a patient's likelihood (0.89×) of developing a perioperative complication ($P < 0.05$), whereas 2 factors had lower odds (0.82). More specifically, patients who were diabetes, obese, and had hypertension had the greatest odds at developing a complication (0.58 [0.58–0.57]) followed by those who had concomitant hypertension, high triglycerides, and were obese (0.55 [0.63–0.48]; all $P < 0.001$). MetS patients with 2 factors, being obese and having hypertension produced the lowest odds at developing a complication (0.5 [0.61–0.43]; $P < 0.001$). These MetS patients also had a lower length of stay than those with 3 and 4 ($P < 0.001$).

Conclusions: Metabolic patients improved in perioperative complications incrementally, demonstrating the utility of efforts to mitigate burden of MetS even if not completely abolished.

Clinical Relevance: This review contributes to the assessment of MetS optimization in the field of adult spine surgery.

Level of Evidence: 3.

Complications

Keywords: metabolic syndrome, spine, complications, comorbidity

INTRODUCTION

Metabolic syndrome (MetS) refers to an amalgamation of medical disorders related to insulin resistance that increase the risk for cardiovascular morbidity and mortality.[1] It is defined as having a body mass index ≥30 kg/m^2 as well as 2 of the following: hyperlipidemia, hypertriglyceridemia, hypertension, or diabetes.[2] Risk factors for the development of this syndrome have been quoted to include old age, a sedentary lifestyle, and genetic predisposition.[1] Nearly 50 million people in the United States meet the criteria for MetS, and the incidence of this syndrome is increasing at a dramatic rate, posing a major public health challenge.[2] Studies have linked the presence of MetS to increased health risks in the general population; however, research evaluating its impact during and after elective spinal surgery is sparse.[1]

With the increased need for spine surgery, along with the increasing prevalence of MetS, it is imperative to

assess the effects MetS can have on perioperative and postoperative outcomes. The current literature reveals that MetS has been shown to negatively affect perioperative outcomes in spine surgery. In particular, MetS has been shown to be an independent risk factor for higher postoperative complications, nonroutine discharge, increased readmissions, length of hospital stay, and time to return to independent function.[3,4] Since the diseases encompassing MetS are objective and modifiable, gaining a better understanding of the effects of MetS on surgical outcomes can allow for preoperative optimization to minimize perioperative burden and enhance recovery.[3,5]

The purpose of this study is to utilize the National Inpatient Sample database to compare the demographics and complications in patients with MetS undergoing elective spinal surgery compared to those without MetS. Consequently, this study will assess the incremental value of improving the individual components of MetS in relation to clinical outcomes. Previous studies conducted on this topic either had small sample sizes or only looked at specific procedures in spinal surgery. To the authors' knowledge, the present study provides the largest sample size for surgical outcomes following all types of elective spinal surgery in patients with MetS.

MATERIALS AND METHODS

Data Source and Study Design

This is a retrospective cohort study using Nationwide Inpatient Sample (NIS) hospital discharge data from the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project. The NIS constitutes one of the largest publicly available all-payer databases in the United States, and is comprised data from more than 7 million hospital stays. More information about the NIS can be found at the following link: https://www.hcup-us.ahrq.gov/db/nation/nis/nisdbdocumentation.jsp.

Study Population

Elective spine surgery patients between 2007 and 2016 in NIS were isolated by the International Classification of Diseases, ninth edition (ICD-9), codes for MetS (hypertension, diabetes, obesity, and triglycerides). MetS was defined by ≥2 of the previously stated factors. Postoperative complications were analyzed. In order to quantify the invasiveness of the surgical procedure as a single objective variable, we employed the previously validated surgical invasiveness scale proposed by Mirza et al.[6] The Mirza surgical invasiveness score is calculated by adding the various procedures (decompression, fusion, instrumentation) performed at each level.

Statistical Analysis

Patient characteristics, including age, sex, and Charlson Comorbidity Index score were assessed with descriptive statistics. χ^2 and t tests compared demographics between metabolic and nonmetabolic patients. Resolution of metabolic factors was incrementally analyzed in regard to postoperative complications through utilization of logistic regressions (OR [95% CI]). All analyses were performed using SPSS software (version 23.0; Armonk, NY, USA). Statistical significance was set to $P < 0.05$.

RESULTS

Cohort Demographics

A total of 2,855,517 elective spine patients were isolated with 20.1% having MetS. Of these metabolic patients, 81.4% had 2 factors, 18.4% had 3 factors, and 0.2% had all 4 factors. Among the metabolic patients, the most common metabolic variable was hypertension (95.9%), followed by diabetes (72.4%), obesity (48.9%), and triglycerides (1.8%). At baseline, metabolic patients were older, less likely to be female, and had more comorbidities (Table 1, $P < 0.001$).

Cohort Surgical Characteristics

Metabolic patients underwent significantly more operations (92.5% vs 88.3%) than nonmetabolic patients (Table 2). More specifically, metabolic patients underwent more invasive procedures, more fusions (67.7% vs 55.5%), and more decompressions (68.8% vs 55%) than nonmetabolic patients. By approach, metabolic patients had experienced more combined (5% vs 4.3%), anterior (22% vs 21.2%), and posterior (39.7% vs 29%; all $P < 0.05$). However, these patients had lower rates of larger 9+ level fusions than nonmetabolic patients (0.7% vs 1.4%; all $P < 0.05$).By surgical timing, less metabolic patients had their procedure done same day

Table 1. Basic demographics of study population.

Demographic	Metabolic	Nonmetabolic	*P* Value
Age, y, mean ± SD	62 ± 12	55.9 ± 16.1	<0.001
Charlson Comorbidity Index, mean ± SD	0.8 ± 1.4	0.6 ± 1.2	<0.001
Women, %	51.3%	53%	<0.001
Procedure invasiveness[6]	3.9	3.2	<0.001

Table 2. Surgical characteristics of study population.

Characteristics	Metabolic	Nonmetabolic	*P* Value
Posterior approach	39.7%	29.0%	<0.001
Anterior approach	22.0%	21.2%	<0.001
Combined approach	5.0%	4.3%	<0.001
Decompression	68.8%	55.0%	<0.001
Fusion	67.7%	55.5%	<0.001
2- to 3-Level fusions	51.8%	43.1%	<0.001
4- to 8-Level fusions	13.6%	9.5%	<0.001
>9-Level fusions	0.7%	1.4%	<0.001

(82.9% vs 81.8%; $P < 0.001$) . More of their procedures were delayed 8+ days (5.2% vs 4.2%; $P < 0.001$).

Postoperative Complications

Metabolic patients had greater postoperative complications than those not diagnosed with MetS (28.8% vs 19.7%). More specifically, there were significantly more medical and surgical complications experienced by metabolic patients for all the items listed in Table 3 except for digestive complications and dysphagia.

Postoperative Complications by Factor Count

Breaking down complications by metabolic factor count, patients with 3 factors had the greatest total complication rate (2 factors: 28.2%, 3 factors: 31.3%, 4 factors: 30.3%). These patients also had the highest rates of surgical complications such as problems related to their device, infections, anemia, and hematomas (Table 4). Consequently, these patients had the highest prevalence of revision surgeries with a rate of 6.4%. Even though patients with 4 factors didn't have the highest complication rate overall, these patients experienced more bowel, bladder, respiratory, and deep vein thrombosis complications ($P < 0.05$). Mortality rate was also highest in these patients (2 factors: 0.3%, 3 factors: 0.2%, 4 factors: 0.7%), as was their rate of surgical intervention (2 factors: 92.2%, 3 factors: 93.5%, 4 factors: 96.6%; $P < 0.001$).

Table 3. Postoperative complications among study population.

Complication	Metabolic	Nonmetabolic	*P* Value
Bowel	9.7%	6.8%	<0.001
Bladder	1.3%	0.9%	<0.001
Neurologic	2.3%	1.4%	<0.001
Dysphagia	0.1%	0.1%	0.34
Cardiac	0.6%	0.4%	<0.001
Respiratory	0.6%	0.4%	<0.001
Digestive	0.3%	0.3%	0.98
Device	3.5%	2.9%	<0.001
Hematoma	1.1%	0.7%	<0.001
Anemia	9.8%	5.9%	< 0.001
Infection	0.9%	0.5%	<0.001
Deep vein thrombosis	0.6%	0.4%	<0.001
Total	28.8%	19.7%	<0.001
Revision surgery	4.5%	5.9%	<0.001

Table 4. Postoperative complications by metabolic factor.

Complication	2 Factors	3 Factors	4 Factors	*P* Value
Bowel	9.5%	10.9%	12.2%	<0.001
Bladder	1.3%	1.4%	1.7%	<0.001
Neurologic	2.3%	2.3%	2.5%	0.82
Dysphagia	0.1%	0.1%	0.0%	0.06
Cardiac	0.6%	0.6%	0.6%	0.37
Respiratory	0.5%	0.6%	0.7%	<0.001
Digestive	0.3%	0.3%	0.0%	0.07
Device	3.5%	3.7%	1.7%	<0.001
Hematoma	1.0%	1.2%	1.0%	<0.001
Anemia	9.5%	11.3%	10.9%	<0.001
Infection	0.8%	1.0%	0.3%	<0.001
Deep vein thrombosis	0.5%	0.7%	1.0%	<0.001
Mortality	0.3%	0.2%	0.7%	<0.001
Length of Stay	4.25 ± 4.9	4.47 ± 4.8	4.27 ± 5.2	<0.001
Total complications	28.2%	31.3%	30.3%	<0.001
Revision surgery	5.9%	6.4%	5.1%	<0.001

Postoperative Complications by Specific Metabolic Factors

Controlling for age and invasiveness, having 3 factors increased a patient's likelihood (0.89×) of developing a perioperative complication ($P < 0.05$), whereas those with 2 factors had lower odds (0.82). More specifically, patients who were diabetes, were obese, and had hypertension had the greatest odds of developing a complication (1.5 [1.4–1.5]). However, this risk decreased by half when at least 1 of the factors was resolved, as seen in Table 5. Patients who had hypertension, were obese, and had high triglyceride levels had an associated risk of complications occurring (OR: 0.66); however, this risk decreased the most with resolving the patient's hypertension (OR: 0.52; all $P < 0.001$). By revision status, patients with 3 factors with the greatest odds of undergoing a revision surgery were diabetes, were obese, and had hypertension (0.82 [0.8–0.84]; $P < 0.001$). However, this risk is decreased when a patient is only diagnosed as being obese and diabetes (0.77 [0.7–0.8]; $P < 0.001$).

DISCUSSION

MetS has grown in prevalence in the general population, increasing by more than 35% between 1988 and 2012 35%.[3] With this increasing prevalence, there is also an increase in MetS patients undergoing spine fusion surgery.[4] Thus, it is imperative to identify which exact metabolic factors present patients with a high risk for complications to alleviate these side effects of surgery with proper preoperative risk evaluation and patient education. The present study identified the risks associated with undergoing spine surgery while being concomitantly diagnosed with MetS. Even though the overall complication rate identified in our study

Table 5. Complications by specific factors of metabolic syndrome.

	Complication Total		Revision	
Factor	**OR**	***P* Value**	**OR**	***P* Value**
Hypertension, diabetes, and trigylcerides	0.67 (0.62–0.73)	<0.001	0.9 (0.7–1.1)	0.36
Hypertension, obesity, and diabetes	1.5 (1.4–1.5)	<0.001	0.82 (0.8–0.84)	<0.001
Hypertension, obesity, and trigylcerides	0.66 (0.58–0.75)	<0.001	0.62 (0.5–0.7)	<0.001
Obesity and trigylcerides	0.52 (0.44–0.62)	<0.001	1.04 (0.7–1.5)	0.82
Hypertension and triglycerides	0.65 (0.1–0.69)	<0.001	0.82 (0.73–0.92)	<0.05
Diabetes and triglycerides	0.63 (0.51)	<0.001	1.8 (0.9–3.4)	0.054
Hypertension and diabetes	0.7 (0.74–0.75)	<0.001	0.88 (1.24–1.25)	<0.001
Hypertension and obesity	0.7 (0.7–0.71)	<0.001	0.82 (0.8–0.84)	<0.001
Obesity and diabetes	0.7 (0.6–0.7)	<0.001	0.77 (0.7–0.8)	<0.001

was higher than those previously published (28.8% vs 8.5%), we can agreeably say that metabolic patients are at a predisposition to developing postoperative complications.[1]

Previous research by Memtsoudis et al found that MetS in patients undergoing posterior lumbar spine fusions was significantly associated with postoperative complications.[1] As identified by these researchers, metabolic patients had an increase odds for major complications (OR: 1.1), longer length of stay (OR: 1.09), and higher hospital costs (OR: 1.25). Similarly, in the current study, metabolic patients had greater cardiac complications, device-related complications, and rates of revision surgery, further adding to health care expenditures.

Overall, 95.9% of the MetS patients in our study had hypertension, and we found that resolving preoperative hypertension had the greatest impact on decreasing risk of complications. The association of preoperative hypertension with end-organ-related major adverse events has been long recognized.[7] Blood pressure is a surrogate measure of perfusion to ischemia-prone end organs like the brain, heart, and kidneys.[7] Patients with a preoperative systolic blood pressure ≥180 mm Hg or diastolic blood pressure ≥110 mm Hg have a significantly increased risk of complications including myocardial ischemia/infarction, dysrhythmias, cerebrovascular events, and renal failure.[8] Furthermore, a study conducted by Browner et at found that the presence of preoperative hypertension increased the OR for postoperative death to 3.8 times that of normotensives.[8] Therefore, surgeons should consider managing uncontrolled hypertension prior to elective spinal surgery to avoid potentially debilitating complications and reduce mortality.

Diabetes (72.4%) and obesity (48.9%) were also prominent in MetS patients in our study and managing these issues can also prevent postoperative complications. Diabetes and obesity are both well-established risk factors for surgical site infection, which remains a common problem among spine surgery patients with its associated increase in morbidity, mortality, hospital length of stay, and cost.[9] Diabetes can affect neural recovery after spine surgery due to coexisting diabetic neuropathy or concomitant small vessel disease, and it is also known to adversely affect bone remodeling and can consequently lead to nonunion following spine surgery.[7,10] Berenholtz et al found that diabetes with chronic complications was independently associated with an increased risk of transfusion following spinal surgery.[11] Red blood cell transfusions have been shown to suppress human T cell proliferation and therefore have been associated with postoperative surgical site and urinary tract infections following spine surgery.[12] Regarding obesity, Elsamadicy et al revealed that obese patients undergoing elective spine surgery have a 2-fold increased rate of 30-day readmission.[13] Furthermore, Epstein's review found that morbidly obese patients undergoing elective spine surgery had markedly increased perioperative risks including infection, more wrong-level surgery, higher incidence of deep venous thrombosis/pulmonary embolism, more pneumonias, increased cardiac complications, brachial and lumbar plexus injuries, and anesthetic risks.[14] With these preventable complications in mind, surgeons should recommend weight loss strategies to obese MetS patients and optimal diabetes control to diabetic MetS patients prior to elective spinal surgery to minimize complications and readmission.

As with most studies that are retrospective in nature, the present study was subject to selection biases and confounding variables. Although analysis of a large, nationwide database lends our study increased generalizability, it also may result in a biased patient population, as patients are identified by exclusively ICD-9 codes. Similarly, complication outcomes were also tracked using ICD-9 codes, introducing the possibility of coding bias into outcomes analysis. Although this study constitutes a step forward, no prospective randomized studies have been performed comparing

preoperative resolution of metabolic factors incrementally to reduce negative outcomes. Well-designed prospective studies to examine the benefit of preoperative planning and patient education are needed.

CONCLUSIONS

This study was able to identify the complications associated with metabolic patients undergoing spine surgery and the benefits of incrementally decreasing each associated factor prior to surgical intervention. Treating a metabolic patient's hypertension first may lead to decreased odds of developing complications, thus demonstrating the utility of efforts to mitigate burden of MetS even if not completely abolishing it.

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