INTERNATIONAL JOURNAL of SPINE SURGERY

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Int J Spine Surg published online 4 December 2023
https://www.ijssurgery.com/content/early/2023/11/30/8539

This information is current as of May 10, 2025.

The International Journal of Spine Surgery
2397 Waterbury Circle, Suite 1,
Aurora, IL 60504, Phone: +1-630-375-1432

International Journal of Spine Surgery, Vol. 00, No. 0, 2023, pp. 1–7
https://doi.org/10.14444/8539

Low Body Mass Index Patients Undergoing an Anterior Lumbar Fusion May Have an Increased Risk of Perioperative Complications

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ABSTRACT

Background: Previous research has shown that underweight patients may be at a greater risk of experiencing postsurgical complications. The purpose of this study was to investigate the association between body mass index (BMI) and postoperative complications following single-level anterior lumbar fusion (ALF).

Methods: All single-level elective ALF procedures performed between 2010 and 2020 were identified in the PearlDiver Mariner Database. Patients were separated into 6 groups based on the World Health Organization BMI classifications. Differences in postsurgical complications (ie, deep vein thrombosis, pulmonary embolism, surgical site infection, hardware malfunction, wound dehiscence, and blood transfusion) among BMI categories were assessed using a χ^2 contingency test.

Results: Results indicated that underweight patients (BMI <20) were at a significantly greater risk of developing deep vein thromboses, experiencing hardware malfunction, and requiring blood transfusion compared with any other BMI classification ($P < 0.001$). Results also demonstrated that underweight individuals had similar risks of developing surgical site infection and wound dehiscence compared with patients classified as having obesity class III.

Conclusion: Underweight patients may be at a greater risk than currently believed of experiencing postoperative complications following single-level ALF procedures.

Clinical Relevance: Patients with a BMI of 20 or less should be carefully evaluated prior to surgical intervention to ensure they are optimized for surgery.

Level of Evidence: 3.

Complications

Keywords: BMI, underweight, complications, risk factor

INTRODUCTION

The global prevalence of obesity has tripled over the past 50 years and has become a major contributor to the worldwide burden of disease. Specific to the United States, the prevalence of obesity has followed the worldwide trend, with approximately 40% of the population now considered obese.[1] Obesity is a major health care problem that can lead to premature disability and death by increasing the risk of cardiovascular disease, myocardial infarction, hypertension, stroke, diabetes, and certain cancers.[2] Previous studies have established that mortality is associated with obese body mass index (BMI) categories as well as underweight categories, suggesting that individuals at each end of the spectrum may have increased risks.[3]

Given the high prevalence of obesity and the large body of literature describing the negative effects associated with high BMIs, it stands to reason that the majority of studies in orthopedics focus on modifiable risks associated with obesity. Studies have indicated that obese individuals are 1.53 times more likely to seek care for lower back pain.[4] Additionally, obesity has also been shown to be an independent risk factor for postoperative complications related to surgical site infections (SSIs), venous thromboembolism, and blood loss in patients undergoing spine surgery.[5–8]

However, recent studies have begun to describe an obesity paradox in which patients considered underweight (BMI <18.5) may be at a similar or greater risk of postsurgical complications compared with obese individuals.[9] Underweight patients have been shown to be at an increased risk of postoperative complications across multiple surgical disciplines, including nonbariatric general surgery,[10,11] total joint replacement,[12,13] and spine surgery.[14–16] However, these studies often provide inconsistent results.[14]

Over the past few decades, there has been an increased utilization of the anterior approach for lumbar fusions (ALFs). ALF procedures promote vertebral arthrodesis to treat various pathologies such as degenerative disc disease, spondylolisthesis, and discogenic back pain.[17] However, with only 2% of the population classified as underweight, there is a paucity of information detailing the associations between low BMI and postsurgical complications in patients undergoing ALFs.[5] Therefore, the purpose of this study was to utilize a large all-claims database to investigate whether underweight patients undergoing an ALF have an increased risk of postoperative complications. Given the associations between low BMI and complications in other surgical disciplines, it was hypothesized that patients undergoing ALFs with a low BMI would have an elevated risk of postoperative complications compared with other BMI classifications.

METHODS

This study was a secondary data analysis using the PearlDiver Mariner database (PearlDiver Technologies, Colorado Springs, CO, USA), a proprietary web-based research platform that contains adjudicated medical claims from Commercial, Medicare, Medicaid, government, and cash payers. At the time this study was performed, there were more than 91 million records from 2010 through 2020. All data were provided in an aggregate form and were void of all protected health information. Patients were identified through a combination of Current Procedural Technology (CPT) and International Classification of Diseases, Tenth Revision (ICD-10) codes. This study was reviewed by our institutional review board and deemed to be "not human subjects research."

Patient records were queried to identify those who had a single-level lumbar spinal fusion using CPT code concerning single-level fusions or interbody fusions using an anterior approach (CPT codes 22558 and 22585). Patient records were filtered to exclude all patients younger than 18 years, patients undergoing surgical intervention due to a trauma and/or pathological fracture, and patients with a history of malignancy/cancer. Additionally, patients with known eating disorders (eg, anorexia and bulimia) were also excluded; however, the intersection within the study groups and eating disorders was fewer than 11 patients. The resulting patient list was then filtered to include only the first instance to reduce the possibility that staged procedures were included in the data set. Patients were then divided into 6 groups to categorize BMI using ICD-10 codes (Table 1). ICD-10 codes categorize all patients with a BMI <20 into the same group; as a result, the underweight BMI category in this study was adjusted to include patients with a BMI of 20 (kg/m^2) or less rather than using the World Health Organization (WHO) definition of less than 18.5 (kg/m^2).[18]

The primary outcomes of interest for this study were postoperative complications within 90 days of the index procedure and included deep vein thrombosis (DVT), pulmonary embolism (PE), blood transfusion (BT), SSI, wound dehiscence (WD), and hardware malfunction (HM). Using Boolean language, complications were identified using ICD-10 codes (Supplemental Table 1). All of the complications except HM were identified using the predefined cohorts within the PearlDiver database. HM was defined as a specified or unspecified mechanical failure of an internal orthopedic prosthetic device, internal fixation device, other orthopedic devices, implants or grafts on initial encounter, displacement of internal fixation device of vertebrae on initial encounter, or other mechanical complications of internal fixation device of vertebrae on initial encounter.

Statistical Methods

All statistical analyses were performed using R studio software version 3.6.1 embedded within the PearlDiver application. General descriptive statistics were used to describe all parameters of interest, continuous data were presented as means and SDs, discrete data were presented as medians and ranges, and binary data were presented as the percentage of the total study population. Differences in outcomes between BMI categories were assessed using a χ^2 contingency test. Given that

Table 1. ICD-10 codes used to categorize patients according to their BMI.

BMI (Category)	ICD-10 Codes
<20 (underweight)	ICD-10-D-R636 and ICD-10-D-Z681
20–24.9 (normal weight)	ICD-10-D-Z6820, ICD-10-D-Z6821, ICD-10-D-Z6822, ICD-10-D-Z6823, and ICD-10-D-Z6824
25–29.9 (overweight)	ICD-10-D-Z6825, ICD-10-D-Z6826, ICD-10-D-Z6827, ICD-10-D-Z6828, and ICD-10-D-Z6829
30–34.9 (obesity class I)	ICD-10-D-Z6830, ICD-10-D-Z6831, ICD-10-D-Z6832, ICD-10-D-Z6833, and ICD-10-D-Z6834
35–39.9 (obesity class II)	ICD-10-D-Z6835, ICD-10-D-Z6836, ICD-10-D-Z6837, ICD-10-D-Z6838, and ICD-10-D-Z6839
>40 (obesity class III)	ICD-10-D-Z6841, ICD-10-D-Z6842, ICD-10-D-Z6843, ICD-10-D-Z6844, and ICD-10-D-Z6845

Abbreviations: BMI, body mass index; ICD-10, International Classification of Diseases, Tenth Revision.

Table 2. Demographic characteristics of patients for each BMI category (*N* = 14,468).

Demographics	Underweight (BMI <20) *n*	Underweight (BMI <20) %	Normal Weight (BMI 20–24.9) *n*	Normal Weight (BMI 20–24.9) %	Overweight (BMI 25–29.9) *n*	Overweight (BMI 25–29.9) %	Obesity Class I (BMI 30–34.9) *n*	Obesity Class I (BMI 30–34.9) %	Obesity Class II (BMI 35–39.9) *n*	Obesity Class II (BMI 35–39.9) %	Obesity Class III (BMI >40) *n*	Obesity Class III (BMI >40) %
n	494	3.4%	1702	11.8%	3433	23.7%	4120	28.5%	2767	19.1%	1952	13.5%
Age, y												
<40	43	8.7%	200	11.8%	379	11.0%	483	11.7%	333	12.0%	282	14.4%
40–49	73	14.8%	318	18.7%	682	19.9%	844	20.5%	658	23.8%	493	25.3%
50–59	141	28.5%	447	26.3%	940	27.4%	1142	27.7%	795	28.7%	564	28.9%
60–69	129	26.1%	382	22.4%	822	23.9%	1052	25.5%	659	23.8%	431	22.1%
70–79	89	18.0%	347	20.4%	594	17.3%	581	14.1%	311	11.2%	174	8.9%
80–84	<11	0.0%	<11	0.0%	13	0.4%	12	0.3%	<11	0.0%	<11	0.0%
Sex												
Woman	355	71.9%	1160	68.2%	2065	60.2%	2482	60.2%	1798	65.0%	1382	70.8%
Man	139	28.1%	542	31.8%	1368	39.8%	1638	39.8%	969	35.0%	570	29.2%

Abbreviation: BMI, body mass index.

15 tests were performed to understand the interactions between BMI groups, an adjusted alpha was used to address the potential for Type I errors; therefore, a *P* value of 0.003 or less was considered to be a statistically significant finding.

RESULTS

A total of 14,468 patients were included in this study. Patients were placed into 1 of the 6 BMI categories, with the largest portion of patients categorized as obesity class I and the smallest portion classified as underweight (Table 2).

The incidence of DVT, PE, HM, and BT was significantly higher in the underweight group compared with all other groups. Additionally, the incidence of SSI was significantly higher in the obesity class III group compared with all other groups. WD was found to be significantly higher in the underweight group compared with all groups except for obesity class III, which had a similar rate of WD compared with the underweight group (Figure).

DISCUSSION

While many studies have shown that obesity is associated with postoperative complications following spinal procedures,[19–22] there have been significantly fewer studies conducted to explore the relationships between underweight patients and postoperative outcomes.[16] The paucity of literature may be related to the fact that only 2% of the US population are considered underweight, whereas more than 40% are considered obese.[1,23] Nevertheless, understanding the implications of operating on an underweight patient is of clinical importance; therefore, the purpose of this study was to better understand the associations between BMI and postoperative complications among ALF patients. To our knowledge, this is currently the largest study investigating the relationship between underweight individuals and complications following single-level ALF.

Results indicated that the prevalence of all 6 perioperative complications were elevated in the underweight group when compared with the normal weight group. Furthermore, underweight patients had a significantly greater risk of experiencing DVT, PE, HM, and BT compared with all other BMI categories. Although not statistically significant, there was a trend indicating a decreased risk of PE in relation to increasing BMI, with the overweight and obesity class I BMI groups having the lowest PE risk. This protective trend is consistent with the literature concerning the "obesity paradox."[9,10,24] Previous studies have shown that a low BMI is common in patients with osteoporosis,[25] which may explain the increased rate of hardware failure noted in the underweight group because these patients may have poor bone quality, making fixation more difficult to achieve.[26,27] Regarding the increased prevalence of BT in the underweight group, studies have suggested that patients with low BMI may suffer from malnutrition and thus may be anemic.[28–35] Therefore, patients who already have low hemoglobin prior to surgery may require additional blood product to prevent significant anemia from surgical blood loss.[35,36] However, it is important to note that a secondary look at the data to understand the distribution of anemia among the study groups was relatively similar. The rate of anemia was found to be 25% in the underweight group, 20.9% in the normal weight group, 21.1% in the overweight group, 23% in the obesity class I group, 22.8% in the obesity class II group, and 25.6% in the obesity class III group. Interestingly, the greatest prevalence within the groups occurred in the underweight and obesity class III groups, which mirrors the U-shaped curve for complications. Further research is necessary to fully

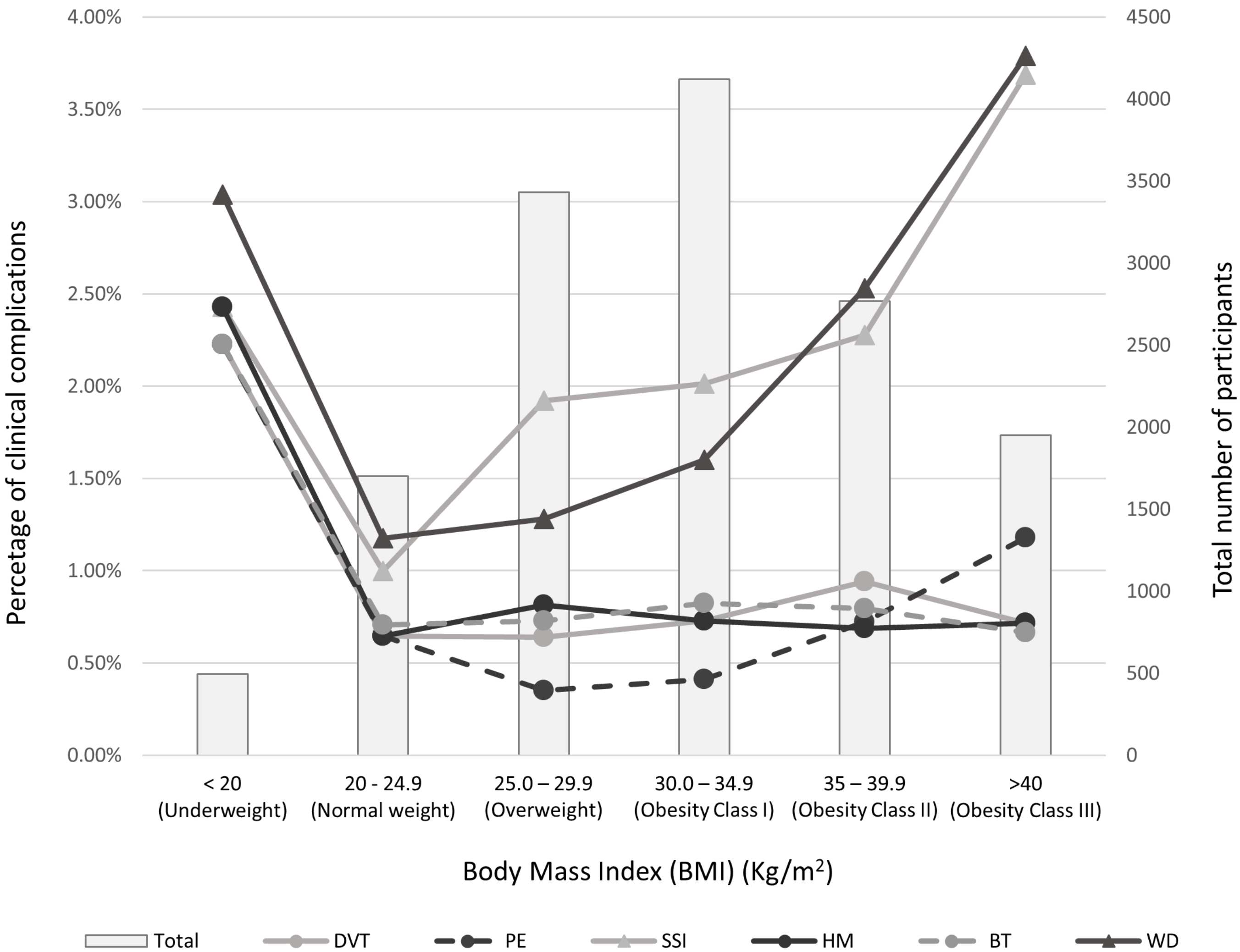

Figure. Adverse events after anterior lumbar fusion as a function of body mass index. Abbreviations: BT, blood transfusion; DVT, deep vein thrombosis; HM, hardware malfunction; PE, pulmonary embolism; SSI, surgical site infection; WD, wound dehiscence.

understand the relationship between anemia and BMI given the incidental finding that obesity class III and underweight individuals have similar distributions.

The results of this study also indicated that the rates of SSIs and WD were similar between the underweight group and the obesity class III group. These complications may be increased in underweight populations due to the need for additional BT, which is a known risk for SSIs, as well as the fact that the underweight group may also have nutritional deficits that could increase their potential for developing an infection or reduce their ability to heal.[37,38]

Contrary to other published studies, the data presented in this study demonstrated that DVT did not increase with increasing BMI. This inconsistency may be a result of increased utilization of Enhanced Recovery After Surgery programs over the past 10 years. These programs promote accelerated recovery by decreasing a patient's surgical stress and organ dysfunction while optimizing their physiological function as well as promoting increased thromboembolism prophylaxis and early mobilization.[39]

It is also important to note that the underweight group included in this study may have disparate representation of 2 separate populations: those who are naturally underweight and those who are underweight due to an underlying condition. However, it is important to note that this study attempted to focus primarily on patients who are naturally underweight by excluding cancer, pathological fracture, eating disorders, and traumatic causes for their spinal fusion. That being said, there are limitations to using the PearlDiver database, and previous studies have shown that a low BMI and changes in body weight are risk factors for osteoporosis.[25] Osteoporosis can be considered a contraindication for spinal surgery, particularly with bone fusions and instrumentation. Decreased mechanical properties due to reduced mineralization offer poor purchase and pullout strength of fixation implants and increase the risk of fixation failure.[26,27] Our low BMI cohort may have a lower bone mineral density compared with the other BMI groups, thus having a higher prevalence of hardware failures; however, data on bone density are not available within the PearlDiver database, and therefore, its relationship to our patient population cannot be determined. Although bone density was unavailable, it was possible through a secondary analysis of the data to demonstrate the prevalence of osteoporosis within each of the study cohorts. Overall, the data suggested a similar prevalence of osteoporosis in each group with 16% in the underweight group, 14.5% in the normal weight group, 16% in the overweight group, 23.7% in the obesity class I group, 30% in the obesity class II group, and 26.4% in the obesity class III group. Given these distributions and the rates of hardware failures, the results suggest that osteoporosis alone does not explain the rate of hardware failure especially given that the rate is much higher in the underweight group, while the osteoporosis rate is not. However, as previously mentioned, the data in this study require a billable code to be identified, and patients within each group may not have received a formal diagnosis of osteoporosis within the timeframe that this study addresses.

The results of this study were consistent with previous works indicating that underweight and obesity class III groups were at the greatest risk of developing postoperative complications[16] and were further supported by a study indicating that readmission rates in the underweight population were significantly greater than those in normal weight individuals.[15] It is important to recognize that the results of this study contradict the results of Bono et al, who indicated that patients with a BMI of 35 or greater were at the greatest risk of postoperative complications.[5] However, the differences in results between our study and those of Bono et al may be due to the fact that this study limited the analysis to single-level ALF, while Bono et al analyzed all lumbar spine surgeries. Therefore, additional work should be directed to better understand the relationship between low BMI and other lumbar spine surgical procedures and approaches.

There are several potential limitations within this investigation. This is a retrospective analysis and therefore it cannot determine a causal relationship between BMI and perioperative outcomes. The results of this study were obtained using a univariate analysis of the data allowing for the potential for confounding variables. Significant findings in a univariate analysis may not maintain significance in a multivariate analysis or with the use of propensity score matching. An additional limitation of this study is the use of ICD-10 codes to categorize the full spectrum of BMI groups. The WHO has defined normal BMI to be between 18.5 and 24.9 kg/m^2 and underweight to be less than 18.5 kg/m^2.[18] However, ICD-10 codes categorize all patients with a BMI less than 20 kg/m^2 into the same group. This inability to fully identify underweight individuals may have skewed the results by including some patients considered to be normal weight.[40] However, despite the fact that some normal weight patients were considered underweight by our study design, the results still provided significant findings, suggesting that patients with a BMI lower than 20 kg/m^2 were at a greater risk of postoperative complications. Future studies that define an underweight population in accordance with the WHO may find stronger relationships than those noted in our findings. Additionally, PearlDiver does not provide access to patient-level data, and all data are provided in aggregate form based on billable codes, both to identify and analyze the patient population. Therefore, there is limited ability to control for comorbidities that may not be diagnosed until outside the timeframe analyzed for this study, as well as the fact that testing results (eg, bone mineral density) are not available, thus limiting analysis to a very binary understanding of whether a patient has or does not have a specific diagnosis.

CONCLUSION

In summary, this study provides further data to support that low BMI is associated with an increased risk of multiple postoperative complications following ALF, suggesting that underweight individuals should be considered an at-risk population for ALFs. Surgeons and medical staff should be cognizant of this fact and, therefore, may want to consider additional presurgical optimization plans for underweight patients.

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Funding: The authors received no financial support for the research, authorship, and/or publication of this article.

Declaration of Conflicting Interests: The authors report no conflicts of interest in this work.

IRB Approval: This study was approved (deemed not human subject research) by our institution's IRB.

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