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ORIGINAL ARTICLE

The Effect of Height on Adverse Short-Term Outcomes Following Lower-Extremity Bypass Surgery in Subjects with Diabetes Mellitus

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Background: The objective of this investigation was to evaluate adverse short-term outcomes following open lower extremity bypass surgery in subjects with diabetes mellitus with a specific comparison performed based on subject height.

Methods: The American College of Surgeons National Surgical Quality Improvement Program database was analyzed to select those subjects with CPT codes 35533, 35540, 35556, 35558, 35565, 35566, 35570 and 35571 and with the diagnosis of diabetes mellitus. This resulted in 83 subjects ≤60 inches, 1084 subjects >60 inches and <72 inches, and 211 subjects ≥72 inches.

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Results: No differences were observed between groups with respect to the development of a superficial surgical site infection (9.6% vs. vs. 6.4% vs. 5.7%; p=0.458), deep incisional infection (1.2% vs. 1.4% vs. 2.8%; p=0.289), sepsis (2.4% vs. 2.0% vs. 2.8%; p=0.751), unplanned reoperation (19.3% vs. 15.6% vs. 21.8%; p=0.071), nor unplanned hospital readmission (19.3% vs. 14.8% vs. 17.1%; p=0.573). A significant difference was observed between groups with respect to the development of a wound disruption (4.8% vs. 1.3% vs. 4.7%; p=0.001). A multivariate regression analysis was performed of the wound disruption outcome with the age, gender, race, ethnicity, height, weight, current smoker and open wound/wound infection variables. Race (p=0.025) and weight (p=0.003) were found to be independently associated with wound disruption, but height was not (p=0.701).

Conclusions: The results of this investigation demonstrate no significant difference in short-term adverse outcomes following the performance of lower extremity bypass surgery based on patient height.

The assessment of and intervention for peripheral arterial disease is an undisputed critical consideration in the treatment of lower extremity tissue loss (1-6). The American College of Surgeons (ACS) National Surgical Improvement Program (NSQIP) has been well-mined with

respect to short-term adverse outcomes following lower extremity revascularization in these situations (7-26). These studies have established several risk factors for short-term adverse outcome following lower extremity revascularization including smoking and the presence of diabetes. However, one patient demographic variable that might affect outcomes and has been relatively understudied might be patient height.

Taller patients, with physically longer nerves and arteries, have previously been found to be at an increased risk for the development of peripheral neuropathy, fracture, and some vascular diseases (27-33). Ferriol et al. found that tall stature was associated with left ventricular hypertrophy (31). Roetker et al. found an increased risk of venous thromboembolism with increasing height (32). Tseng found that increasing height was an independent predictor of lower extremity amputation in over 250,000 patients with diabetes (33). Further, several investigations have demonstrated an increased association between height and peripheral neuropathy, and additionally between peripheral neuropathy and adverse outcomes following lower extremity surgery (34-36). Conversely, others have hypothesized that shorter stature might result in decreased extremity blood pressures and subsequently the more sensitive diagnosis of peripheral arterial disease (37,38).

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The objective of this investigation was to evaluate adverse short-term outcomes from a large US database following open lower extremity bypass surgery with a comparison performed based on subject height.

Materials and Methods

The 2018 American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) database was analyzed for the purposes of this investigation. This is a registry aimed at quality improvement undertaken by the American College of Surgeons and consists of hundreds of participating hospitals. The database is deidentified and does not require IRB approval for access and use. More information on this database might be found on their website (www.facs.org/quality-programs/acs-nsqip) and within the User Guide (39).

We chose to include the 8 current procedural terminology (CPT) codes available within the database related to lower extremity bypass grafting: 35533 (axillary bifemoral bypass graft), 35540 (aortobifemoral bypass graft), 35556 (femoral popliteal bypass graft), 35558 (femoral-femoral bypass graft), 35565 (iliofemoral bypass graft), 35566 (femoral-tibial bypass), 35570 (tibial-tibial bypass graft), and 35571 (popliteal-tibial bypass graft). We additionally required the variable “diabetes mellitus with oral agents or insulin” for inclusion. We chose to

categorize subject height into three groups based on previous publications investigating height as a risk factor for adverse outcome: 1) ≤60 inches,2) >60 inches and <72 inches, 3) ≥72 inches.

Extracted information included variable labels "age", "gender", "new race", "ethnicity Hispanic", "weight", "functional health status prior to surgery", "ASA classification", "estimated probability of mortality", "estimated probability of morbidity", "total operation time", "length of total hospital stay", "current smoker within one year", "congestive heart failure (CHF) in 30 days before surgery", "hypertension requiring medication", "currently on dialysis (pre-op)", "open wound/wound infection", "occurrences of superficial incisional SSI", "occurrences of deep incisional SSI", "occurrences of wound disruption", "occurrences of sepsis", "unplanned reoperation", and "unplanned readmission" as defined by the ACS NSQIP User Guide (39).

The primary outcome measures were considered a frequency count of superficial surgical site infection, deep incisional infection, wound disruption, sepsis, unplanned readmission, and unplanned reoperation within 30 days of the index procedure.

Data was stored in a password protected personal computer for subsequent statistical analysis. All statistical analyses were performed by one study author (AJM) using Statistical Analysis Systems software, version 9.2 (SAS Institute, Cary, NC). Categorical variables were considered in terms of the frequency count and compared between groups by means of the Kruskal-Wallis statistic. Continuous variables were considered in terms of the mean, standard

deviation and range and compared between groups by means of analysis of variance (ANOVA). Any adverse clinical outcome demonstrating statistical significance between groups was additionally analyzed with a multivariate analysis to include any demographic variable with a p-value <0.10 on between group analysis.

Results

This resulted in 83 subjects ≤60 inches, 1084 subjects >60 inches and <72 inches, and 211 subjects ≥72 inches. A comparison between groups (height ≤60 inches vs. height >60 inches and <72 inches vs. height ≥72 inches) of demographic information is provided in Table 1. Significant differences between groups were observed with the age ($p<0.001$), gender ($p<0.001$), race ($p<0.001$), ethnicity ($p=0.002$), height ($p<0.001$), weight ($p<0.001$), current smoker ($p=0.006$), and total operation time ($p=0.004$) variables. Subjects ≤60 inches of height were observed to be relatively older, of female gender, of less weight, and were less frequently current smokers. Subjects ≥72 inches were observed to be more frequently of male gender, of heavier weight, and with longer total operation times.

Results of the primary outcome measures are displayed in Table 2. No differences were observed between groups with respect to the development of a superficial surgical site

infection (9.6% vs. vs. 6.4% vs. 5.7%; p=0.458), deep incisional infection (1.2% vs. 1.4% vs. 2.8%; p=0.289), sepsis (2.4% vs. 2.0% vs. 2.8%; p=0.751), unplanned reoperation (19.3% vs. 15.6% vs. 21.8%; p=0.071), nor unplanned hospital readmission (19.3% vs. 14.8% vs. 17.1%; p=0.573). A significant difference was observed between groups with respect to the development of a wound disruption (4.8% vs. 1.3% vs. 4.7%; p=0.001).

A multivariate regression analysis was performed of the wound disruption outcome with the age, gender, race, ethnicity, height, weight, current smoker and open wound/wound infection variables (Table 3). Race (p=0.025) and weight (p=0.003) were found to be independently associated with wound disruption.

Discussion

As with any scientific investigation, critical readers are encouraged to review the study design and specific results in order to reach their own independent conclusions, while the following represents our conclusions based on the preceding results. We also never consider data to be definitive, but do think that these results might be worthy of attention and future investigation.

From information collected and analyzed from a large US database, we observed no differences in adverse short-term outcomes following lower extremity bypass surgery in

subjects with diabetes with a comparison performed based on subject height. No adverse short-term post-surgical outcome differences were observed with respect to superficial infection (p=0.458), deep infection (p=0.289), sepsis (p=0.751), unplanned reoperations (p=0.071), nor umplanned readmissions (p=0.573). A difference was observed with respect to wound disruption (p=0.001), but height was not identified on multivariate regression analysis to be independently associated (p=0.701).

All scientific investigations have limitations, and this one has several important limitations to consider. First, as data was collected from an existing database, we are restricted to only the available information and the original extraction from the medical records. In other words, we cannot personally speak to the accuracy of the data and were unable to collect any data points not found within the database. With that said, the ACS NSQIP database represents one of the largest US surgical outcome registries and has been well-mined and published in the peer-reviewed surgical literature. Second, the database only contains information on short-term (30-day) adverse outcomes, and therefore we cannot speak to anything occurring with these subjects after 30 days. Third, height is of course a non-modifiable patient characteristic. This means these results are unlikely to affect treatment interventions but might affect patient education in the perioperative period. Based on these specific results, height would not be

expected to substantially affect outcomes following open lower extremity revascularization. And finally, all retrospective comparison investigations are at risk of an inherent and confounding selection bias, and this investigation is no different. Many patient variables would be expected to influence short-term outcomes following lower extremity bypass. We chose to include those variables most relevant to physicians working with lower extremity tissue loss.

In conclusion, the results of this investigation demonstrate no significant difference in short-term adverse outcomes following the performance of lower extremity bypass surgery based on patient height.

Financial Disclosure: None reported.

Conflict of Interest: None reported.

References

[1] Schaper NC, Andros G, Apelqvist J, et al: Diagnosis and treatment of peripheral arterial disease in diabetic patients with a foot ulcer. A progress report of the International Working Group on the Diabetic Foot. Diabetes Metab Res Rev 28: 218, 2012.

[2] Frykberg RG, Zgonis T, Armstrong DC, et al: Diabetic foot disorders. A clinical practice guideline (2006 revision). J Foot Ankle Surg 45: S1, 2006.

[3] Hingorani A, LaMuraglia GM, Henke P, et al: The management of the diabetic foot: A clinical practice guideline by the Society for Vascular Surgery in collaboration with the American Podiatric Medical Association and the Society for Vascular Medicine. J Vasc Surg 63: 3S, 2016.

[4] Sumpio BE, Armstrong DG, Lavery LA, et al: The role of interdisciplinary team approach in the management of the diabetic foot: a joint statement from the Society for Vascular Surgery and the American Podiatric Medical Association. J Vasc Surg 51: 1504, 2010.

[5] Pinzur MS, Slovenkai MP, Trepman E, et al: Guidelines for diabetic foot care: recommendations endorsed by the Diabetes Committee of the American Orthopaedic Foot and Ankle Society. Foot Ankle Int 26: 113, 2005.

[6] Lipsky BA, Berendt AR, Cornia PB, et al: 2012 Infectious Diseases Society of America clinical practice guideline for the diagnosis and treatment of diabetic foot infections. Clin Infect Dis 54: e132, 2012.

[7] Zhang JQ, Curran T, McCallum JC, et al: Risk factors for readmission after lower extremity bypass in the American College of Surgeons National Surgery Quality Improvement Program. J Vasc Surg 59: 1211, 2014.

[8] Greenblatt DY, Rajamanickam V, Mell MW: Predictors of surgical site infection after open lower extremity revascularization. J Vasc Surg 54: 433, 2011.

[9] Crawford RS, Cambria RP, Abularrage CJ, et al: Preoperative functional status predicts perioperative outcomes after infrainguinal bypass surgery. J Vasc Surg 51: 351, 2010.

[10] LaMuraglia GM, Conrad MF, Chung T, et al: Significant perioperative morbidity accompanies contemporary infrainguinal bypass surgery: an NSQIP report. J Vasc Surg 50: 299, 2009.

[11] Madenci AL, Ozaki CK, Gupta N, et al: Perioperative outcomes of elective inflow revascularization for lower extremity claudication in the American College of Surgeons National Surgical Quality Improvement Program database. Am J Surg. 212: 461, 2016.

[12] Nakazawa KR, Cornwall JW, Rao A, et al: Trends, factors, and disparities associated with length of stay after lower extremity bypass for tissue loss. J Vasc Surg 73: 190, 2021.

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[13] Najafian A, Selvarajah S, Schneider EB, et al: Thirty-day readmission after lower extremity bypass in diabetic patients. J Surg Res 200: 356, 2016.

[14] Collins TC, Johnson M, Henderson W, et al: Lower extremity nontraumatic amputation among veterans with peripheral arterial disease: is race an independent factor? Med Care 40: 1106, 2002.

[15] Giles KA, Hamdan AD, Pomposelli FB, et al: Body mass index: surgical site infections and mortality after lower extremity bypass from the National Surgical Quality Improvement Program 2005-2007. Ann Vasc Surg 24: 48, 2010.

[16] Singh N, Sidawy AN, DeZee KJ, et al: Factors associated with early failure of infrainguinal lower extremity arterial bypass. J Vasc Surg 47: 556, 2008.

[17] Chen SL, Whealon MD, Kabutey NB, et al: Outcomes of open and endovascular lower extremity revascularization in active smokers with advanced peripheral arterial disease. J Vasc Surg 65: 1680, 2017.

[18] Rao A, Baldwin M, Cornwall J, et al: Contemporary outcomes of surgical revascularization of the lower extremity in patients on dialysis. J Vasc Surg 66: 167, 2017.

apma Advancing foot and ankle medicine and surgery | Journal of the American Podiatric Medical Association

[19] Lancaster RT, Conrad MF, Patel VI, et al: Predictors of early graft failure after infrainguinal bypass surgery: a risk-adjusted analysis from the NSQIP. Eur J Vasc Endovasc Surg 43: 549, 2012.

[20] O'Hare AM, Sidawy AN, Feinglass J, et al: Influence of renal insufficiency on limb loss and mortality after initial lower extremity surgical revascularization. J Vasc Surg 39: 709, 2004.

[21] Aziz F, Bohr T, Lehman EB: Wound disruption after lower extremity bypass surgery is a predictor of subsequent development of wound infection. Ann Vasc Surg 43: 176, 2017.

[22] Aziz F, Lehman EB, Reed AB: Unplanned return to operating room after lower extremity arterial bypass is an independent predictor for hospital readmission. J Vasc Surg 63: 678, 2016.

[23] Aziz F, Chu Y, Lehman EB: Lower extremity bypass surgery on patients transferred from other hospitals is associated with increased morbidity and mortality. Ann Vasc Surg 41: 205, 2017.

[24] Aziz F, Lehman E, Blebea J, et al: Postoperative complications after lower extremity bypass increase the risk of new deep vein thrombosis. Phlebology 33: 558, 2018.

[25] Peacock MR, Shah NK, Farber A, et al: Index complications predict secondary complications after infrainguinal lower extremity bypass for critical limb ischemia. J Vasc Surg 65: 1344, 2017.

[26] Robinson WP, Mehaffey JH, Hawkins RB, et al: Lower extremity bypass and endovascular intervention for critical limb ischemia fail to meet Society for Vascular Surgery's objective performance goals for limb-related outcomes in a contemporary national cohort. J Vasc Surg 68: 1438, 2018.

[27] Kote GS, Bhat AN, Thajuddeen K, et al: Peripheral insensate neuropathy – is height a risk factor? J Clin Diagn Res. 7: 296, 2013.

[28] Cheng YJ, Gregg EW, Kahn HS, et al: Peripheral insensate neuropathy – a tall problem for US adults? Am J Epidemiol. 164: 873, 2006.

[29] Sorensen L, Molyneaux L, Yue DK: Insensate versus painful diabetic neuropathy: the effects of height, gender, ethnicity and glycaemic control. Diabetes Res Clin Pract. 57: 45, 2002.

[30] Bjornerem A, Bui QM, Ghasem-Zadeh A, et al: Fracture risk and height: an association partly accounted for by cortical porosity of relatively thinner cortices. J Bone Min Res 28: 2017, 2013.

[31] Ferriol C, Tremols S, Jimenez C, et al: Are there height-dependent differences in subclinical vascular disease in hypertensive patients? J Clin Hypertension 16: 70, 2014

apma Advancing foot and ankle medicine and surgery | Journal of the American Podiatric Medical Association

[32] Roetker NS, Armasu SM, Pankow JS, et al: Taller height as a risk factor for venous thromboembolism: a Mendelian randomization meta-analysis. J Thromb Haemost 15: 1334, 2017.

[33] Tseng CH: Prevalence of lower-extremity amputation among patients with diabetes mellitus: is height a factor? CMAJ 174: 319-23, 2006.

[34] Wukich DK, Crim BE, Frykberg RG, et al: Neuropathy and poorly controlled diabetes increase the rate of surgical site infection after foot and ankle surgery. J Bone Joint Surg 96: 832, 2014.

[35] Wukich DK, McMillen RL, Lowery NJ, et al: Surgical site infections after foot and ankle surgery: a comparison of patients with and without diabetes. Diabetes Care 34: 2211, 2011.

[36] Wukich DK, Joseph A, Ryan M, et al: Outcomes of ankle fractures in patients with uncomplicated versus complicated diabetes. Foot Ankle Int 32: 120, 2011.

[37] Menez SP, Kwak L, Ding N, et al: The association of height with incident peripheral arterial disease in the arthrosclerosis risk in communities (ARIC) study. Circulation 139: P308, 2019.

[38] Fu X, Zhao S, Mao H, et al: Association of height with peripheral arterial disease in type 2 diabetes. J Endocrinol Invest 38: 57, 2015.

apma Advancing foot and ankle medicine and surgery | Journal of the American Podiatric Medical Association

[39] User Guide for the 2018 ACS NSQIP Participant Use Data File. Available at:

https://www.facs.org/-/media/files/quality-programs/nsqip/nsqip_puf_userguide_2018.ashx.

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Table 1: Demographic comparison between height cohorts

Variable^	Height ≤60 inches (n=83)	Height >60 and <72 inches (n=1084)	Height ≥72 inches (n=211)	Statistical Comparison^
Age (years)	70.82 ± 9.57 (51-89)	66.73±9.76 (25-88)	66.08 ± 8.95 (40-86)	P<0.001*
Male gender	7 (8.4%)	747 (68.9%)	211 (100.0%)	P<0.001*
Race^^	W: 41 (49.4%) B/AA: 16 (19.3%) U/NR: 22 (26.5%) A: 4 (4.8%) AI/AN: 0 (0.0%) NH/PI: 0 (0.0%)	W: 675 (62.3%) B/AA: 182 (16.8%) U/NR: 201 (18.5%) A: 18 (1.7%) AI/AN: 3 (0.3%) NH/PI: 5 (0.5%)	W: 146 (69.2%) B/AA: 47 (22.3%) U/NR: 18 (8.5%) A: 0 (0.0%) AI/AN: 0 (0.0%) NH/PI: 0 (0.0%)	P<0.001*
Ethnicity	Hispanic: 21 (25.3%) Not: 53 (63.9%) Unknown: 9 (10.8%)	Hispanic: 110 (10.1%) Not: 811 (74.8%) Unknown: 163 (15.0%)	Hispanic: 4 (1.9%) Not: 187 (88.6%) Unknown: 20 (9.5%)	P=0.002*
Height (inches)	58.69 ± 1.74 (49-60)	66.70±2.93 (61-71)	73.37 ± 1.40 (72-78)	P<0.001*

Weight (pounds)	141.57 ± 28.59 (87-217)	187.49±40.10 (79-420)	228.50 ± 47.0 (133-425)	P<0.001*
Pre-Operative Functional Health Status	Independent: 74 (89.2%) Partially/Fully Dependent: 9 (10.8%)	Independent: 992 (91.5%) Partially/Fully Dependent: 92 (8.5%)	Independent: 191 (90.5%) Partially/Fully Dependent: 20 (9.5%)	P=0.710
Current smoker	16 (19.3%)	398 (36.7%)	76 (36.0%)	P=0.006*
Hypertension	77 (92.8%)	950 (87.6%)	187 (88.6%)	P=0.368
Congestive heart failure	2 (2.4%)	41 (3.8%)	6 (2.8%)	P=0.673
Dialysis	7 (8.4%)	81 (7.5%)	18 (8.5%)	P=0.841
Open wound/wound infection	36 (43.4%)	517 (47.7%)	118 (55.9%)	P=0.055
Wound classification	1: 76 (91.6%) 2: 3 (3.6%) 3: 1 (1.2%) 4: 3 (3.6%)	1: 981 (90.5%) 2: 39 (3.6%) 3: 27 (2.5%) 4: 37 (2.4%)	1: 189 (89.6%) 2: 10 (4.7%) 3: 6 (2.8%) 4: 6 (2.8%)	P=0.875
ASA classification	1: 0 (0.0%) 2: 1 (1.2%)	1: 2 (0.2%) 2: 10 (0.9%)	1: 0 (0.0%) 2: 3 (1.4%)	P=0.305

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	3: 53 (63.9%) 4: 29 (34.9%) 5: 0 (0.0%)	3: 765 (70.6%) 4: 305 (28.1%) 5: 2 (0.2%)	3: 140 (66.4%) 4: 67 (31.8%) 5: 1 (0.5%)	
Estimated probability of morbidity	0.1726 ± 0.071 (0.08-0.44)	0.1716±0.066 (0.04-0.49)	0.1742 ± 0.073 (0.08-0.53)	P=0.877
Estimated probability of mortality	0.0260 ± 0.036 (0.0-0.20)	0.0220±0.030 (0.00-0.26)	0.0258 ± 0.043 (0.0-0.36)	P=0.190
Total operation time (minutes)	251.53 ± 112.92 (31-543)	249.92±108.50 (18-718)	277.54 ± 117.09 (25-684)	P=0.004*
Total length of hospital stay (days)	8.33±6.11 (0-26)	8.82±7.78 (0-67)	8.65 ± 6.83 (1-40)	P=0.824

^Categorical data is reported in terms of a frequency count (percentage) and compared by means of the Kruskal-Wallis statistic. Continuous data is reported in terms of the mean ± standard deviation range and compared by means of analysis of variance (ANOVA).

^^American Indian or Alaska Native (AI/AN), Asian (A), Black or African American (B/AA), Native Hawaiian or Pacific Islander (NH/PI), Unknown or Not Reported (U/NR), White (W).

*Level of significance defined as $p<0.05$.

Table 2: Comparison of short-term adverse outcomes between height cohorts

Outcome	Height ≤60 inches (n=83)	Height >60 and <72 inches (n=1084)	Height ≥72 inches (n=211)	Statistical Comparison^
Superficial surgical site infection (%)	8 (9.6%)	69 (6.4%)	12 (5.7%)	P=0.458
Deep incisional infection (%)	1 (1.2%)	15 (1.4%)	6 (2.8%)	P=0.289
Wound disruption (%)	4 (4.8%)	14 (1.3%)	10 (4.7%)	P=0.001*
Sepsis (%)	2 (2.4%)	22 (2.0%)	6 (2.8%)	P=0.751
Any unplanned reoperation (%)	16 (19.3%)	169 (15.6%)	46 (21.8%)	P=0.071
Any unplanned hospital readmission (%)	16 (19.3%)	160 (14.8%)	36 (17.1%)	P=0.573

^Categorical data is reported in terms of a frequency count and compared by means of the Kruskal Wallis statistic. Level of significance defined as $p<0.05$.

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Table 3: Regression analysis of wound disruption outcome

Variable	Significance
Age	0.142
Gender	0.108
Race	0.025*
Ethnicity	0.337
Height	0.701
Weight	0.003*
Current smoker	0.240
Open wound/wound infection	0.400

A multivariate regression analysis was performed of the "wound disruption" short-term adverse outcome as it displayed significance between groups. Any demographic variable with a p-value <0.10 between groups was included in the regression analysis.