Predictive value of lateral soft tissue thickness for complications after total hip arthroplasty with a lateral incision

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ABSTRACT

The purpose of this study was to determine the relationship between soft tissue thickness lateral to the greater trochanter, as measured on anteroposterior pelvis radiograph, and postoperative complications following primary total hip arthroplasty. A retrospective review of 1110 consecutive patients treated at a single institution from 2003 to 2011 was conducted. Postoperative complications were divided into surgical site infections, deep wound infections, noninfectious surgical complications, need for revision surgery, and medical complications. Lateral soft tissue thickness (LSTT) was measured as the horizontal distance from the most lateral point on the greater trochanter to the skin edge obtained from anteroposterior hip radiographs. Among the 1110 study patients, 19.19% had a postoperative complication, with a deep infection rate of 3.42%. Of the previously identified risk factors, increased LSTT and body mass index were both associated with surgical site infection and deep infection, and LSTT was associated with revision surgery. An LSTT value of >5 cm was predictive of surgical site infection, deep infection, and revision surgery. This easily obtainable radiographic measurement, along with clinical examination near the operative site, might prove helpful in making preoperative risk assessments.

KEYWORDS Lateral soft tissue thickness; surgical site infections; total hip arthroplasty

It is projected that by 2030, over half of patients undergoing total joint arthroplasty will be obese.^{1,2} Many studies have identified an association between obesity and postoperative complications in total hip arthroplasty (THA),^{3–11} and periprosthetic joint infections are expected to increase over this time period.² Conversely, other studies have shown that obesity has no association with complications in arthroplasty.^{12–16} The true contribution of obesity to complications following THA may be underestimated by using body mass index (BMI) to define obesity. BMI does not distinguish adiposity from lean mass and has been shown to misclassify 28% of men and 48% of women as obese or nonobese.^{17–19} A higher percentage of body fat, as measured using bioelectrical impedance analysis, has been associated with poorer outcomes in THA, while comparisons using BMI were not significantly different.²⁰ Studies in spine surgery suggest that the amount of adipose tissue in the region

of the planned operation may be a better predictor of surgical site complications than total adiposity.^{21,22} Bernaus et al found an increased risk for surgical site infection after hip fracture surgery associated with excessive local subcutaneous fat thickness as measured on radiograph.¹⁰ However, their study cohort included only four THA procedures. No similar associations have been identified in the setting of primary THA. In this study, we performed a retrospective cohort analysis to explore the hypothesis that lateral soft tissue thickness (LSTT) as measured on radiographs may be predictive of complications after primary THA.

METHODS

Institutional review board approval was obtained prior to beginning the study. A retrospective review of 1110 consecutive patients treated at a single institution from 2003 to 2011 was performed. All surgeries consisted of primary THA

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Figure 1. The measurement of lateral soft tissue thickness from a supine, postoperative anteroposterior radiograph of the hip.

through an approach that utilizes a lateral incision (posterior, lateral, and anterolateral approaches) from one of 10 primary surgeons at a single institution. Data collected from electronic medical records included age, sex, BMI, presence of diabetes mellitus, occurrence of revision surgery, and postoperative complications. Postoperative complications were divided into surgical site infection (superficial wound infections), deep wound infection (defined using the American Academy of Orthopedic Surgeons diagnostic guidelines), noninfectious surgical complications (dehiscence, loose components, prosthetic dislocation, intraoperative fracture, and deep vein thrombosis/pulmonary embolism), need for revision surgery, and medical complications (pneumonia, cerebrovascular event, myocardial infarction, urinary tract infection, death, bladder infection, heel ulcer, gastric ulcer, sepsis secondary to cholecystitis, gastrointestinal bleeding, renal failure, respiratory failure, and ileus).²³

LSTT, a novel measurement introduced in this study, was measured as the horizontal distance from the most lateral point on the greater trochanter to the skin edge, using the standing hip radiographs obtained within 1 year of the surgery date (Figure 1). Measurements were made using picture

archiving and communications systems imaging software (GE Centricity Enterprise Web V3.0, Fairfield, CT). Patients were excluded from the analysis if appropriate x-rays were not available within 1 year of the surgery date or if the skin edge was not visible due to either cassette positioning or extremely large hip girth. Using these criteria, 367 patients were excluded.

A total of 1110 patients were included. The independent *t* test, Kruskal-Wallis test, and chi-square test were used to compare demographics with respect to complications. Univariate logistic regression models were performed on the entire data set (1100 patients) to assess any association between risk factors (LSTT, age, length of stay, BMI, diabetes mellitus, and sex) with the postoperative complication outcomes. A multivariable model was then selected using the results from the univariate analysis as well as from a score model selection method. The patients were randomly divided in two equal groups of 550 to allow for testing and validation of a multivariable model. The selected final model was first run on the *test data set* and then on the *validation data set* for the purposes of validating the model. The parameter estimates and their 95% confidence intervals for both data sets were compared. If the confidence intervals were found to be similar, we concluded that the model was valid.

A receiver operating characteristic analysis was performed to determine at which tissue thickness the likelihood of a complication became significantly more likely. This cutoff point was selected based on the maximization of sensitivity and specificity as well as other factors including the concordance statistics and the positive predictive value. An LSTT cutoff of 5 cm was selected because it maximized the sensitivity and specificity of the association with complications and because it was a clinically reasonable value. This LSTT cutoff point was then applied to the remainder of the patients to establish the predictive capabilities of LSTT with regards to surgical site infection, deep infection, and revision surgery.

RESULTS

The mean age of our study sample was 66.3 years (standard deviation [SD] 12.5); women made up 54.9% and men, 45.1%. The mean BMI in the sample was 28.88 kg/m² (SD 5.6), while the median LSTT was 44.3 mm (range 1.6 to 168.6). The overall postoperative complication rate was 19.2%, with a surgical site infection rate of 4.4%, deep infection rate of 3.42%, revision surgery rate of 2.9%, noninfectious surgical complication rate of 7.0%, and medical complication rate of 9.0%. Table 1 presents bivariate comparison results with associated *P* values.

Univariate regression analysis over the test data showed that only LSTT (odds ratio [OR] 1.02 per increasing mm; confidence interval [CI] 1.00, 1.03; *P*=0.01) was significantly associated with an increased risk of surgical site infection; BMI, age, sex, diabetes, and length of stay were not (*P*=0.06, 0.11, 0.30, 0.63, 0.17, respectively). BMI, age, sex, and diabetes were not found to fit the final multivariable

Table 1. Bivariate comparisons between complication outcomes and patient demographics, BMI, and lateral soft tissue thickness

Variable	Median BMI (kg/m ²) (range)	Median LSTT (mm) (range)	Mean age (years) (SD)	Men (%)	Women (%)	Diabetes (%)	No diabetes (%)
Surgical site infection	<i>P</i> = 0.003	<i>P</i> = 0.002	<i>P</i> = 0.03	<i>P</i> = 0.98	<i>P</i> = 0.98	<i>P</i> = 0.09	<i>P</i> = 0.09
No	28.1 (10.1–50.2)	43.8 (1.6–168.6)	66.5 (12.5)	476 (45.1%)	580 (54.9%)	147 (13.9%)	912 (86.1%)
Yes	31.4 (18.0–42.5)	58.0 (11.9–166.1)	62.4 (12.8)	22 (44.9%)	27 (55.1%)	11 (22.5%)	38 (77.6%)
Deep infection	<i>P</i> = 0.001	<i>P</i> ≤ 0.0001	<i>P</i> = 0.04	<i>P</i> = 0.48	<i>P</i> = 0.48	<i>P</i> = 0.03	<i>P</i> = 0.03
No	28.1 (10.1–50.2)	43.6 (1.6–168.6)	66.4 (12.5)	483 (45.3%)	584 (54.7%)	148 (13.8%)	922 (68.2%)
Yes	31.5 (18–42.5)	70.1 (11.9–166.1)	61.9 (13.0)	15 (39.5%)	23 (60.5%)	10 (26.3%)	28 (73.7%)
Postoperative revision	<i>P</i> = 0.63	<i>P</i> = 0.0003	<i>P</i> = 0.30	<i>P</i> = 0.008	<i>P</i> = .008	<i>P</i> = 0.80	<i>P</i> = 0.80
No	28.2 (10.1–50.2)	43.6 (1.6–135.1)	66.3 (12.5)	491 (45.8%)	582 (54.2%)	153 (14.2%)	923 (85.8%)
Yes	29.2 (18.1–49.5)	59.7 (23.1–168.6)	63.7 (11.3)	7 (21.9%)	25 (78.1%)	5 (15.6%)	27 (84.4%)
Noninfectious surgical complications	<i>P</i> = 0.46	<i>P</i> = 0.07	<i>P</i> = 0.21	<i>P</i> = 0.46	<i>P</i> = 0.46	<i>P</i> = 0.77	<i>P</i> = 0.77
No	28.2 (10.1– 50.2)	43.6 (1.6–166.1)	66.1 (12.4)	466 (45.4%)	561 (54.6%)	146 (14.2%)	884 (85.8%)
Yes	29.0 (19.8–49.5)	49.4 (6.9–168.6)	68.0 (13.1)	32 (41.0%)	46 (59.0%)	12 (15.4%)	66 (84.6%)
Medical complications	<i>P</i> = 0.48	<i>P</i> = 0.11	<i>P</i> < 0.0001	<i>P</i> = 0.29	<i>P</i> = 0.29	<i>P</i> = 0.02	<i>P</i> = 0.02
No	28.2 (10.1–50.2)	45 (1.6–168.6)	65.6 (12.4)	458 (45.6%)	547 (54.4%)	136 (13.5%)	872 (86.5%)
Yes	29.0 (19.8–49.5)	37.5 (8–166.1)	72.1 (11.5)	40 (40.0%)	60 (60.0%)	22 (22.0%)	78 (78.0%)

BMI indicates body mass index; LSTT, lateral soft tissue thickness.

*Noninfectious complications and medical complications were associated with length of stay (5 days [3–13], *P* = 0.0433) and (5 [3–17], *P* < 0.0001), respectively. Otherwise, length of stay was not associated with the other outcome variables.

Table 2. Multivariate regression logistic model of the test and validation data sets

Variable	Surgical site infection			Deep infection			Revision surgery		
	Odds ratios	95% CI	<i>P</i> value	Odds ratio	95% CI	<i>P</i> value	Odds ratio	95% CI	<i>P</i> value
Test data set									
LSTT	1.018	(1.002, 1.033)	.002	1.027	(1.010,1.044)	.002	1.022	(1.004, 1.041)	.02
Age	0.980	(0.949, 1.011)	.17	0.976	(0.942,1.011)	.17	0.982	(0.946, 1.020)	.35
Sex	N/A	N/A	N/A	N/A	N/A	N/A	0.844	(0.535, 6.358)	.33
Diabetes status	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Validation data set									
LSTT	1.020	(1.004, 1.035)	.0004	1.032	(1.014,1.050)	.0004	1.021	(0.995, 1.048)	.11
Age	0.985	(0.953, 1.018)	.75	0.993	(0.955-1.034)	.75	1.010	(0.949, 1.074)	.76
Sex	N/A	N/A	N/A	N/A	N/A	N/A	1.648	(0.303, 8.961)	.56
Diabetes status	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

LSTT indicates lateral soft tissue thickness. BMI did not fit the multivariable model selection criteria for any outcome measure.

model selection criteria. Multivariable analysis of the *test data set* showed a significant relationship between LSTT and surgical site infection (OR 1.02 per increasing mm [CI: 1.00, 1.03], *P* = 0.02) (*Table 2*). This was also significant in multivariable analysis of the *validation data set* (OR 1.02 per increasing mm [CI: 1.00, 1.04], *P* = 0.01). Multivariable analysis of both data sets revealed no significant association

between age and surgical site infection (*P* = 0.20 and *P* = 0.36, respectively).

Univariate regression analysis over the test data showed that both LSTT (OR 1.03 per increasing mm [CI: 1.01, 1.04], *P* < 0.001) and BMI (OR 1.10 per increasing 1 unit [CI: 1.03, 1.19], *P* = 0.009) were significantly associated with an increased risk of deep infection; age, sex, diabetes,

Figure 2. Probability of (a) surgical site infection, (b) deep infection, and (c) revision surgery associated with lateral soft tissue thickness.

and length of stay were not ($P=0.06$, 0.31 , 0.33 , and 0.12 , respectively). BMI, sex, and diabetes were not found to fit the final multivariable model selection criteria. Multivariable analysis of the *test data set* showed a significant relationship between LSTT and deep infection (OR 1.03 per increasing mm [CI: 1.01, 1.04], $P=0.002$). This was also significant in multivariable analysis of the *validation data set* (OR 1.03 per increasing mm [CI: 1.02, 1.06], $P<0.001$). Multivariable analysis of both data sets revealed no significant association between age and deep infection ($P=0.17$ and $P=0.75$, respectively).

In univariate regression analysis of the test data, both LSTT (OR 1.03 per increasing mm [CI: 1.01, 1.04], $P<0.001$) and female sex (OR 3.02 [CI: 1.10, 8.32], $P=0.03$) were significantly associated with increased risk for the need for revision surgery; age, BMI, diabetes status, and length of stay were not ($P=0.22$, 0.38 , 0.91 , and 0.81 ,

respectively). BMI, age, and diabetes status were not found to fit the final multivariable model selection criteria. Multivariable analysis of the *test data set* found that LSTT was a significant risk factor for revision surgery (OR 1.02 per increasing mm [CI: 1.01, 1.04], $P=0.02$). However, multivariable analysis of the *validation data set* found that this relationship was not significant (OR 1.02 per increasing mm [CI: 1.00, 1.05], $P=0.11$). Multivariable analysis of either data set did not find age ($P=0.35$ and $P=0.75$, respectively) or female sex ($P=0.33$ and $P=0.56$, respectively) to be significant risk factors for revision surgery.

BMI, LSTT, and rates of diabetes mellitus were higher in patients with noninfectious surgical complications. However, bivariate analyses and univariate regression analysis did not detect a statistically significant association between these factors, or any other variables, and the risk for noninfectious surgical complications. Univariate regress analysis of age, BMI, diabetes status, sex, and length of stay resulted in P values of 0.41 , 0.40 , 0.10 , 0.96 , 0.44 , respectively.

Univariate regression analysis demonstrated that both increased age (OR 1.05 per increasing year [CI: 1.02, 1.08], $P=0.001$) and length of stay (OR 1.35 per increasing day [CI: 1.16, 1.57], $P<0.0001$) were associated with increased risk of medical complications; LSTT, BMI, sex, and diabetes were not ($P=0.90$, 0.36 , 0.99 , and 0.25 , respectively). BMI, sex, and diabetes were not found to fit the final multivariable model selection criteria. Multivariable analysis of the *test data set* found that age was a significant risk factor for medical complications (OR 1.05 per year [CI: 1.02, 1.09], $P<0.001$). This relationship was confirmed in multivariable analysis of the *validation data set* (OR 1.05 per year [CI: 1.02, 1.09], $P<0.001$). However, LSTT was not a significant risk factor in multivariable analysis of either data set ($P=0.64$ and $P=0.93$, respectively).

In the receiver operator characteristic analysis, the best cut point for LSTT was found to be 5 cm. The positive predictive values for this cut point were 6.1% for surgical site infection, 5.9% for deep infection, and 4.1% for revision surgery (Figure 2); the figure also shows associated probabilities.

DISCUSSION

While previous studies in spine and hip fracture surgery have shown that soft tissue thickness is correlated with surgical site infections, our study is the first to demonstrate that LSTT on radiograph is associated with increased risk of postoperative infection and revision surgery following primary THA.^{10,21,22} To our knowledge, it is also the first study to utilize a simple measurement obtained from routine radiographs to predict risk of postoperative complications in primary THA.

In this study, both BMI and LSTT were significantly associated with postoperative infection. However, the difference in median BMI between the patients who developed an infection and those who did not was only 3.4 kg/m^2 (31.5 vs

28.1 kg/m²) for surgical site infections and 3.3 kg/m² (31.4 vs 28.1 kg/m²) for deep infection. This subtle difference in BMI, although statistically significant, may not lead to useful clinical guidelines for preoperative risk assessments using BMI alone. Small differences in BMI cannot reliably be correlated with differences in percentage of body fat, as BMI has been shown to be a poor marker for true adiposity.²⁴ This was illustrated in a study from Ledford et al which found that complications following THA were not associated with obesity defined using BMI, but were associated with obesity defined using percentage of body fat.²⁰ Percentage of body fat can be calculated using dual-energy x-ray absorptiometry, bioelectrical impedance analysis, or a series of clinical anatomic measurements in combination with BMI. These are costly to the patient and/or inconvenient to obtain. Patients who developed a deep infection in our study had a median LSTT that was 26.5 mm larger (70.1 vs 43.6 mm) than those who did not. This median difference in fat thickness should be clinically obvious on physical exam and pelvis radiograph, perhaps leading to a more useful clinical marker for complications following THA.

LSTT was associated with risk for revision surgery (OR 1.02 per increasing mm [CI: 1.01, 1.04], $P=0.02$) in multivariable analysis of the *test data set*. However, this relationship was not found to be statistically significant using multivariable analysis of the *validation data set* (OR 1.02 per increasing mm [CI: 1.00, 1.05], $P=0.11$). This likely reflects the need for further study of this particular relationship. LSTT and revision surgery had strong associations in univariate (OR 1.03 per increasing mm [CI: 1.01, 1.04], $P<0.001$) and bivariate ($P<0.001$) analyses, helping to support this relationship. BMI was not associated with revision surgery in bivariate, univariate, or multivariate analyses. This further suggests that LSTT may be a better predictor than BMI for overall postoperative complications in THA, possibly the result of LSTT being a more accurate estimate of actual percentage of body fat. Further studies are necessary to confirm this hypothesis.

LSTT gives the surgeon a better understanding of the expected local soft tissue environment around the surgical site and may lead to improved preoperative risk assessment and surgical counseling. *Figure 2* demonstrates that a threshold thickness of 5 cm of lateral fat might be an appropriate point to consider preoperative interventions to address an unacceptable degree of obesity. LSTT is potentially a modifiable risk factor, and dietary and activity modifications may be the best first step for these high-risk patients. Bariatric surgery can also be considered for this patient group, although this alone has not been shown to decrease wound complications in arthroplasty.²⁵

Surgical approach may also affect the soft tissue environment encountered at the surgical site. A CT-based study found that incision site soft tissue thickness was greater for approaches that utilize a lateral hip incision (posterior, lateral, and anterolateral approaches) than those using an

anterior incision (direct anterior and variations of the Hueter or Smith-Petersen approaches).²⁶ All surgeries in the current study were performed using a lateral hip incision. Thus, further studies are required to examine the predictive ability of LSTT for complications following THA with an anterior incision. Other studies have found increased rates of wound complications requiring reoperation with anterior approaches compared to lateral approaches.^{27,28}

Limitations of this study include the retrospective manner of collecting data and the exclusion of patients with LSTT extending beyond the edge of the film. Both factors may lead to sample bias, but excluding very large patients would not be expected to change the strong associations seen in our data since these patients would be at the highest risk for complications. The overall complication rate of 19.2% in our study could be considered high. Complication rates appear to be correlated with many factors, including patient population and reporting styles, with documented rates of 19.1% in Medicare patients, 9% in Veteran's Affairs patients, and 3% in all others.^{29,30} This study did not assess markers for patient malnutrition, which has been associated with obesity and increased risk of complications.^{31,32} Lateral to the greater trochanter is only one area where excessive fat distribution increases risk. Increased thigh girth, for instance, has been shown to potentially increase the risk of dislocation.⁴

In conclusion, increased LSTT as measured on radiograph was associated with increased risk of postoperative infection and revision surgery after primary THA. This easily obtainable radiographic measurement, along with clinical examination near the operative site, might provide helpful data in making preoperative risk assessments.

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