Thickness of the Subcutaneous Fat as a Risk Factor for Surgical Site Infection Following Fragility Hip Fracture Surgery

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Abstract

Introduction: Surgical site infection (SSI) following fragility hip fracture (FHF) surgery is associated with increased morbidity and mortality. Significance: Prediction of patients at risk for SSI is fundamental. We aimed to determine whether subcutaneous radiographic fat measurement (SRM) is associated with increased SSI risk. Methods: A retrospective case-control comparison of SRMs at 3 locations around the hip. Patients diagnosed with SSI in the first postoperative year were matched with age, gender, surgical year, Charlson’s co-morbidity index score, and surgical type controls, not diagnosed with SSI, at a 1:2 ratio. Measurements included the distance between (1) the sourcil to skin surface (SS), (2) the tip of the greater trochanter to skin surface (TGTS), and (3) the most prominent lateral aspect of the greater trochanter to skin surface. Results: 1430 patients were operated during the study period, of whom 45 patients presented with a diagnosis of SSI and compared to 90 controls. Infections occurred 27.4 (± 24.8) days following surgery. SRM significantly differed between groups, and all were higher in the study group; SS, 86.8 ± 25.5 cm vs 74.2 ± 15.3 cm; TGTS, 59.8 ± 26.3 cm vs 47.0 ± 15.8 cm; and LGTS, 45.4 ± 25.1 cm vs 33.2 ± 15.1 cm (P = .003, .004, and .004, respectively). Intraclass correlation coefficients (intra-rater) were high for all measurements (.999 for all). Intraclass correlation coefficients (inter-rater) for SS, TGTS and LGTS were high, .749 (.663.815), .792 (.719.847) and .817 (.751.866), respectively. Conclusions: SRMs were found to be a valid and reproducible tool for predicting high risk of SSI in geriatric patients sustaining FHF.

Keywords

subcutaneous radiographic fat measurements, hip fracture, surgical site infection, post-operative infection, proximal femoral fractures

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Introduction

Surgical site infection (SSI) is a devastating complication following fragility hip fracture (FHF) surgery, associated with deteriorated walking ability, loss of independence, increased medical costs, and increased mortality.1,2 Particularly, when SSI occurs, the reported rates of 90-day mortality triple, and one-year mortality doubles reaching over 50%.2,4 Several factors were identified as related with SSI, amongst which are age, assisted living, diabetes mellitus,

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immunosuppression, liver and kidney diseases, warfarin treatment, tobacco and alcohol consumption, peripheral vascular disease, and obesity. As body mass index (BMI) does not take into consideration body composition, it is not a specific predictor for SSI, and body fat percentage was found to be a more sensitive and precise measurement of SSI risk. Subcutaneous radiographic fat measurement (SRM) is an emerging tool for SSI risk prediction in the field of general surgery and orthopedic surgery.

Due to the devastating consequences of SSI in the fragile FHF population, early identification of risk factors is of critical importance. In this study, we explore whether SRM is associated with increased risk for SSI following fragility hip fracture surgery. We hypothesized that increased subcutaneous fat thickness identified in different SRMs in perioperative radiographs is an independent risk factor for developing SSIs following surgery.

**Materials and Methods**

**Study Design**

Following approval of the institutional review board, a retrospective cohort study of patients 65 years and older, who underwent surgery following fragility hip fractures between January 2011 and June 2018, in a single orthopedic department was conducted. Surgical therapy was defined as closed reduction, open reduction, or hemiarthroplasty (either cemented or cementless, antibiotics was not embedded in the cement). Exclusion criteria were pathological and impending fractures, fracture sustained during hospitalization due to other medical cause (to reduce confounding causes for SSI), fractures sustained over five days before presentation, and patients with technically inadequate radiographs (skin edge not visible due to either cassette positioning or extremely large pelvic girth). For patients who presented with a contralateral fracture during the study period, only the first fracture was included.

All patients who presented with SSI in the first post-operative year were collected and compared to matching controls who did not present with an SSI in a 1:2 ratio. Matching was based upon gender, age, year of surgery, Charlson's co-morbidity index score, and surgical type (fracture fixation or hemiarthroplasty).

**Variables and Measurements**

Primary outcome was defined as the association between SRM and the incidence of SSI in the first post-operative year. Secondary outcome was one-year post-operative mortality.

**Procedure**

Upon arrival to the emergency department, all patients were clinically evaluated by an orthopedic surgeon and x-ray imaging was acquired. Patients were hospitalized either to the orthopedic or the geriatric wards depending on vacancy. Patients admitted to geriatrics were prepared for surgery there, spent the first post-operative day in the orthopedic department, and returned to the geriatric department for the rest of their hospital stay, where a daily orthopedic surgeon assessment was performed. In case the patients had a concurrent active medical problem, they were admitted to an internal medicine department. Surgery was performed within 48 hours of admission unless the patient was determined as clinically unfit for surgery by the anesthesiology team. Following surgery, all patients received daily sessions of respiratory and ambulatory physical therapy. Thromboprophylaxis with low molecular weight heparin (enoxaparin, 40 mg once daily) was routinely initiated on the first post-operative day. For patients under chronic anticoagulant treatment, regular treatment regimen was returned starting POD3 in accordance with physical examination and hemoglobin levels.

**Data Collection**

Demographic data, including 1-year mortality, walking ability, and living arrangements, was collected. The Charlson's comorbidity index (CCI) was used to evaluate patients' co-morbidities. Hospitalization characteristics such as admitting department, time to surgery (defined as time from admission to operating room), implant used for fracture fixation, length of hospital stay (LOS), the need for blood transfusions, in-hospital infections other than SSI, and pre-surgical laboratory values (white blood count, hemoglobin, platelets, creatinine, and international normalized ratio [INR]) were gathered.

The diagnosis and type of SSI was based on accepted Centers for Disease Control (CDC) criteria and established from the hospital records and microbiology results. Intraoperative tissue samples were cultured on blood and MacConkey agar plates, with an extra blood agar plate for anaerobic bacteria. A fraction of the specimen was also incubated in thioglycolate broth for enhanced sensitivity. Upon colonies' growth, bacterial identification was performed using the Bruker MALDI-TOF MS system and/or the Vitek2 system. Antibiogram was performed using disk diffusion assay as well as Etest for minimum inhibitory concentration (MIC), with interpretations based on Clinical and Laboratory Standards Institute (CLSI).

For patients presenting with surgical site infection in the post-operative year, information regarding data related to the infection itself, including results of peripheral blood and of deep tissue cultures obtained during surgery, treatment course, and outcome were collected.

Data was gathered via a shared electronic medical record program, which allows access to data from healthcare facilities countrywide.
Subcutaneous Radiographic Measurements

Radiographic measurements were performed on the pre- or post-operative standardized anteroposterior (AP) pelvis x-rays in the supine position and 1525° of internal rotation of the hips. Subcutaneous fat was measured in three anatomical landmark-based locations as described by others. Measurements included the distance between (1) the sourcil to skin surface (SS), (2) the tip of the greater trochanter to skin surface (TGTS), and (3) the most prominent lateral aspect of the greater trochanter to skin surface (Figure 1).

Radiographs were calibrated using the inserted implant or previously inserted implant of known caliber. For example, in patients with intramedullary nails, the known diameter of the nail was used as a reference for the subcutaneous measurements. In patients with a hemiarthroplasty, the known diameter of the head component was used as reference. Finally, in patients with a dynamic hip screw (DHS), the known cephalic screw length was used as a reference (Figure 2 A-C).

All measurements were taken twice on different occasions for intra-observer correlation. Inter-observer correlation was also obtained.

Statistical Analysis

Continuous variables are presented as mean and standard deviation (SD). Quantitative and ordinal variables are presented as absolute and relative frequencies. The Fisher’s exact tests was used for categorical variables, the Wilcoxon test for ordinal variables, and the Student’s t-test for numeric variables. KaplanMeier survival curves were used to demonstrate 1-year survival. Intra-observer correlation between the two measurements was determined using Pearson’s correlation coefficient All reported P-values will be two-tailed. Statistical significance was defined as P < .05. Statistical analysis was performed using R Core Team (2020) (R: A language and
environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria).

**Results**

1430 patients aged 65 years and older have presented with proximal hip fracture during the study period. Of whom, 46 have returned with a post-operative SSI in the first post-operative year. They were matched with 92 controls who did not present with an SSI. One patient from the study group and 2 patients from the control group did not meet inclusion criteria and were excluded, leaving 45 patients (27 hemiarthroplasties, 15 cemented, and 18 ORIF) and 90 controls (55 hemiarthroplasties, 21 cemented, and 35 ORIF) for analysis.

Demographic characteristics are described in Table 1. Patient demographics and co-morbidities were similar between groups. Most patients in the study group were admitted to the geriatric department (64.4%), while the majority of patients in the control group were admitted to the orthopedic department (58.9%) (\(P = .004\)). Admission INR and anti-coagulation treatment differed, and patients in the study group had a higher rate of anticoagulation treatment and accordingly higher INR values at admission (1.1 ± .2 vs 1.5 ± .8 for the study and control group, respectively, \(P < .001\)). Time to surgery and surgical type were similar. In-hospital medical complications and mortality and LOS did not differ between groups (Table 2). One-year orthopedic complications (other than SSI) were also similar, two dislocations were noted in the infection group, and one peri-prosthetic fracture in the control group. No events of nonunion or cut-out were noted.

Subcutaneous fat measurements significantly differed between groups, and all were higher in the study group (Table 3). This was also true when controlling for the elevated INR values in the study group and when controlling for the admitting department. Notably, hospitalization in the geriatric department was found to be related with increased infection risk regardless of INR and subcutaneous fat measurements. Intraclass correlation coefficients were high for all three measurements (.999 for all). Intraclass correlation coefficients for SS, TGTS, and LGTS for repeated measurements by two observers (inter-rater) were .749 (.663.815), .792 (.719.847) and .817 (.751.866), respectively.

Significant co-linearity exists between fat measurement variables; sourcil to skin surface and tip of greater trochanter to skin surface, Pearson’s \(r = .89\); sourcil to skin surface and lateral greater trochanter to skin surface, Pearson’s \(r = .85\); and tip of greater trochanter to skin and lateral greater trochanter to skin surface, Pearson’s \(r = .94\).

One-year mortality significantly differed between study groups and was higher for the study group (44.4% and 23.3% for the infection and control group, respectively, \(P = .017\) (Figure 3). No significant association was found

### Table 1. Patients’ baseline characteristics.

| Variable                              | Infection (n = 45) | Control (n = 90) | \(P\)-Value Test | Test |
|---------------------------------------|--------------------|------------------|------------------|------|
| Age, average ±SD                      | 83.5 ± 7.7         | 82.9 ± 6.8       | .687             | T-test |
| Gender, n (%)                         |                    |                  |                  |      |
| Female                                | 26 (57.8)          | 49 (54.4)        | .8544            | Fisher |
| Charlson’s comorbidity index, average ± SD| 3.1 ± 2.6         | 2.9 ± 2.6        | .661             | T-test |
| Diabetes mellitus, n (%)              |                    |                  |                  |      |
| None                                  | 18 (40)            | 32 (35.6)        | .706             | Fisher |
| Cane                                  | 10 (23.3)          | 19 (21.8)        | .394             | Wilcoxon rank-sum test |
| Walker                                | 14 (32.6)          | 23 (26.4)        |                  |      |
| Living arrangement, n (%)             |                    |                  |                  |      |
| Home                                  | 26 (57.8)          | 63 (70.8)        | .266             | Fisher |
| Nursing home                          | 6 (13.3)           | 10 (11.2)        |                  |      |
| Home with caregiver                   | 13 (28.9)          | 16 (18.0)        |                  |      |
| Smoking, n (%)                        |                    |                  |                  |      |
| Non-smoker                            | 39 (88.6)          | 64 (77.1)        | .361             | Fisher |
| Current                               | 3 (6.8)            | 10 (12.0)        |                  |      |
| Past                                  | 2 (4.5)            | 9 (10.8)         |                  |      |
| Depression, n (%)                     | 5 (11.1)           | 8 (8.9)          | .760             | Fisher |
| Bisphosphonates use, n (%)            | 2 (4.4)            | 9 (10)           | .336             | Fisher |
| Anticoagulation use, n (%)            | 17 (37.8)          | 8 (8.9)          | < .001           | Fisher |
| Anticoagulation type, n (%)           |                    |                  |                  |      |
| None                                  | 29 (64.4)          | 82 (91.1)        | < .001           | Fisher |
| Warfarin                              | 13 (28.9)          | 4 (4.4)          |                  |      |
| Novel anti-coagulants                 | 3 (6.7)            | 3 (3.3)          |                  |      |
| Low molecular weight heparin          | 0 (0)              | 1 (1.1)          |                  |      |
| Laterality, n (%)                     |                    |                  |                  |      |
| Right                                 | 22 (48.9)          | 45 (50)          | I                | Fisher |

*Data were unavailable for 2 patients from the study group and for 3 patients from the control group.

*Data were unavailable for one patient from the control group.

*Data were unavailable for 7 patients from the study group and for one patient from the control group.
between subcutaneous fat measurements and mortality when controlling for infection.

Table 4 presents information regarding the infection characteristics of the study group. Patients from the study group presented with infection 27.4 (± 24.8) days from surgery. Most (66.6%) were hospitalized in a rehabilitation facility when infection was noted. Treatment regimen was determined according to the patient medical condition, the time elapsed from surgery, fracture union, and surgical type. Most patients (80%) underwent surgery, mainly irrigation and drainage. Some required several interventions. A single bacteria type was cultured in 18 patients. Resistant bacteria were cultured in 10. The most common bacteria cultured were *Staphylococcus aureus* (15, of which 7 were methicillin-resistant *S. aureus*) followed by *Enterobacter* spp. (6), and *Pseudomonas aeruginosa* (5). When blood cultures were available, they mostly demonstrated similar bacteria strains as surgical cultures. Infection was successfully eradicated in 64.4% of patients.

**Discussion**

Subcutaneous radiographic fat measurements were found to be related to surgical site infection risk following fragility hip fracture surgery, in line with our hypothesis. This was true for all three measurements, with a high intra-observer and inter-observer agreement. In-turn, SSI was associated with increased mortality in the first post-operative year.

Elevated subcutaneous radiographic fat measurements are known as a risk factor for SSI in the field of general surgery. Fujii et al. found fat distribution in computerized tomography (CT) scans to be independently associated with SSI in colorectal surgery, and Kozlow et al. have demonstrated similar outcomes between fat distribution measured on CT scans and SSI risk following sternal reconstruction surgery. In orthopedic spinal surgery, Mehta et al. reached comparable conclusions for both surgical cervical and lumbar spine fusions. Interestingly, in the field of joint arthroplasty, the few available studies in the literature reveal conflicting results. When addressing total knee arthroplasty, while Watts et al. have found elevated SRM to be associated with increased risk for SSI, Gupta et al. have actually described higher SRM to be a protective factor. Likewise, following total hip arthroplasty, Sprowls et al. have found thick subcutaneous fat to be related with SSI, while Bell et al. did not reach similar results.

To our knowledge, only a single previous study has suggested an association between the SRM at the hip and the risk of SSI in elderly patients with surgically treated hip fractures. Bernaus et al. have measured subcutaneous fat...
thickness at the level of the tip of the greater trochanter and found a 2.24-cm greater mean SRM to be related with increased infection risk. Our findings are concurring for measurements at three locations, yet we did not find a specific threshold value. When the fat measurements were analyzed as a dichotomous variable with a cutoff at the top quartile, none was found to be associated with increased risk for infection (P value: .060, .060, and .102 for sourcil to skin, lateral greater trochanter to skin, and tip of greater trochanter to skin, respectively) (in accordance with Bell et al’s17 measurements following total hip arthroplasty). Analysis using receiver operator characteristic curves did not find an alternative threshold that is clinically relevant.

Although increased subcutaneous fat measurements were found to be associated with increased risk of infection, in our study, they do not have high enough sensitivity and specificity to be considered as sole predictors of infection.

Several explanations can be suggested for the relation between the increased SRM and the elevated infection risk. First, obese patients’ drug distribution is altered because of different distribution volume, changes in regional blood flow, and different plasma protein binding.26 Even when prophylactic antibiotic dosage is doubled and plasma drug concentration is high, the tissue penetration is substantially lower in obese patients, and was shown to be below the minimum inhibitory concentration for aerobic and anaerobic microorganisms.26,27 Second, an extensive subcutaneous

Table 3. Subcutaneous fat measurements.

| Variable                        | Infection (n = 45) | Control (n = 90) | P-value |
|---------------------------------|--------------------|------------------|---------|
| Place of X-ray imaging, n (%)   |                    |                  |         |
| Intra-operative                 | 19 (21.1)          | 4 (8.9)          | .301    |
| Recovery                        | 45 (50)            | 24 (53.3)        |         |
| Department                      | 16 (17.8)          | 10 (22.2)        |         |
| Follow-up                       | 8 (8.9)            | 4 (8.9)          |         |
| Other                           | 2 (2.2)            | 3 (6.7)          |         |
| Sourcil-to-skin surface (cm), average ± SD | 86.8 ± 25.5    | 74.2 ± 15.3      | .003    |
| Tip of greater trochanter to skin surface (cm), average ± SD | 59.8 ± 26.3    | 47.0 ± 15.8      | .004    |
| Lateral greater trochanter to skin surface (cm), average ± SD | 45.4 ± 25.1    | 33.2 ± 15.1      | .004    |

Adjustment for INR

| Measurement                      | Odds ratio | P-value |
|---------------------------------|------------|---------|
| Sourcil to skin surface         | 1.037      | .003    |
| Tip of greater trochanter to skin surface | 1.036  | .003    |
| Lateral greater trochanter to skin surface | 1.035 | .004    |

Adjustment for INR and hospitalization department

| Sourcil to skin surface         | 1.04       | .002    |
| INR                             | 11.6       | .002    |
| Department (vs orthopedics)     |            |         |
| Geriatrics                      | 3.8        | .003    |
| Internal                        | 17.3       | .058    |
| Tip of greater trochanter to skin surface | 1.04  | .003    |
| INR                             | 12.1       | .002    |
| Department (vs orthopedics)     |            |         |
| Geriatrics                      | 3.8        | .003    |
| Internal                        | 13.6       | .079    |
| Lateral greater trochanter to skin surface | 1.04  | .005    |
| INR                             | 11.3       | .002    |
| Department (vs orthopedics)     |            |         |
| Geriatrics                      | 3.6        | .005    |
| Internal                        | 11.9       | .085    |

INR: international normalized ratio.

*Fat measurements also significant when controlling for anticoagulation use.

Figure 3. One-year survival.
fat tissue is a risk for potential dead space, leading to the accumulation of a seroma or a hematoma, in which an infection can develop. Third, it might be that the thick subcutaneous tissue handling during surgery is more time consuming, leading to a prolonged surgical duration, which in turn is associated with SSI following fragility hip fracture surgery. Finally, the elevated infection risk might be related with the metabolic activity of the subcutaneous fat tissue, which includes proinflammatory cytokine signaling. Limitations of this study include the retrospective manner of data collection. While a patient’s allocation to the orthopedic and geriatric ward was random by nature, we found that infection rate was higher for patients admitted to the geriatric ward, independent of INR and SRM. This might be related to the vicinity of the operated patients to other patients hospitalized perhaps for infectious diseases. We found that while patients who were hospitalized to the geriatric ward had similar rates of DM and PVD at presentation (known risk factors for SSI), the incidence of post-operative infections (pneumonia, urinary tract infection, and sepsis put together) was higher (5.9% for patients in the orthopedic ward and 21.5% for patients in the geriatric ward, \( P = .009 \)). However, due to the retrospective nature of this study, this hypothesis could not be examined, and further studies are required. Lastly, elevated INR values were also found to be related with SSI, independently from SRM. While surgery was performed when INR was 1.5 or lower, a value considered safe for surgery, this could be related to a hematoma formation of to a suggested immunomodulatory effect of warfarin.

**Conclusions**

This study suggests high risk for post-operative SSI in fragility hip fracture patients with elevated SRM. For patients at risk, we recommend special care to be taken for adequate soft tissue approximation during wound closure to reduce seroma, and hematoma formation, and meticulous wound surveillance in the post-operative period, as most patients presented within the first post-operative month while still under medical surveillance in rehabilitation facilities.

**Declaration of Conflicting Interests**

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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**Table 4. Surgical site infection characteristics.**

| Infection characteristic                              | Patients |
|-------------------------------------------------------|----------|
| Time to infection, average (SD)                       | 27.4 (24.8) |
| Location where was the infection noted, n (%)         | Index hospitalization 6 (13.3) |
|                                                      | Rehabilitation 30 (66.7) |
|                                                      | Home 3 (6.7) |
|                                                      | Nursing home 5 (11.1) |
|                                                      | Hospitalization for other cause 1 (2.2) |
| Number of surgeries, n (%)                            | 0 9 (20) |
|                                                      | 1 25 (55.6) |
|                                                      | 2 7 (15.6) |
|                                                      | 3 1 (2.2) |
|                                                      | 4 3 (6.7) |
| Surgical type (1st surgery), n (%)                    | Irrigation and drainage 24 (66.7) |
|                                                      | Staged revision 4 (11.1) |
|                                                      | Hardware removal 8 (22.2) |
| Surgical culture results, n (%)a                      | Monobacterial 18 (56.3) |
|                                                      | Polybacterial 12 (37.5) |
|                                                      | Sterile 2 (6.6) |
| Resistant bacteria, n (%)b                           | No resistance 10 (22.2) |
|                                                      | Resistance 35 (77.8) |
| Treatment outcome, n (%)                              | Infection eradication 29 (64.4) |
|                                                      | Chronic infection under suppression antibiotic therapy 7 (15.6) |
|                                                      | Demise with active infection 9 (20) |

aData were unavailable for 4 patients.

bMethicillin-resistant *Staphylococcus aureus* (7), *Escherichia coli* extended-spectrum beta-lactamase (1), *Klebsiella pneumonia* extended-spectrum beta-lactamase (1), and *Proteus* spp. extended-spectrum beta-lactamase (1).
Author’s Note

Tal Frenkel Rutenberg and Rotem Markman have contributed equally to this work.

Ethical Approval

The study has been performed in accordance with the ethical standards in the 1964 Declaration of Helsinki and approved by the institution review board.

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References

1. Harrison T, Robinson P, Cook A, Parker MJ. Factors affecting the incidence of deep wound infection after hip fracture surgery. J Bone Joint Surg Br. 2012;94-B(2):237-240. doi:10.1302/0301-620X.94B1.27683.
2. Edwards C, Counsell A, Boulton C, Moran CG. Early infection after hip fracture surgery. J Bone Joint Surg Br. 2008;90-B(6):770-777. doi:10.1302/0301-620X.90B6.20194.
3. Pollmann CT, Dahl FA, Rotterdal JHM, Gjertsen J-E, Åmoen A. Surgical site infection after hip fracture - mortality and risk factors: an observational cohort study of 1,709 patients. Acta Orthop. 2020;91(3):347-352. doi:10.1080/17453674.2020.1717841.
4. Frenkel Rutenberg T, Vitenberg M, Yahav D, Spectre G, Velkes S. Surgical site infections in elderly fragility hip fractures patients undergoing warfarin treatment. J Orthop Trauma. 2019;33(10):518-524. doi:10.1097/BOT.0000000000001508.
5. Gallardo-Calero I, Larraínzar-Coghen T, Rodríguez-Pardo D, et al. Increased infection risk after hip hemiarthroplasty in institutionalized patients with proximal femur fracture. Injury. 2016;47(4):872-876. doi:10.1016/j.injury.2015.12.032.
6. Noailles T, Brueléfert K, Chalopin A, Longis PM, Gouin F. What are the risk factors for post-operative infection after hip hemiarthroplasty? Systematic review of literature. Int Orthop. 2016;40(9):1843-1848. doi:10.1007/s00264-015-3033-y.
7. Sathiyakumar V, Greenberg SE, Molina CS, Thakore RV, Obrenzkey WT, Sethi MK. Hip fractures are risky business: an analysis of the NSQIP data. Injury. 2015;46(4):703-708. doi:10.1016/j.injury.2014.10.051.
8. Frenkel Rutenberg T, Velkes S, Vitenberg M, et al. Morbidity and mortality after fragility hip fracture surgery in patients receiving vitamin K antagonists and direct oral anticoagulants. Thromb Res. 2018;166:106-112. doi:10.1016/j.thromres.2018.04.022.
9. Bernaus M, Anglès F, Escudero B, Veloso M, Matamala A, Font-Vizcarra L. Subcutaneous radiographic measurement: A marker to evaluate surgical site infection risk in elderly hip fracture patients. J Bone Jt Infect. 2019;4(1):27-32. doi:10.7150/jbji.30158.
10. Waisbren E, Rosen H, Bader AM, Lipsitz SR, Rogers SO, Eriksson E. Percent body fat and prediction of surgical site infection. J Am Coll Surg. 2010;210(4):381-389. doi:10.1016/j.jamcollsurg.2010.01.004.
11. Ledford CK, Milikkan PD, Nickel BT, et al. Percent body fat is more predictive of function after total joint arthroplasty than body mass index. J Bone Joint Surg Am. 2016;98(10):849-857. doi:10.2106/JBJS.15.00509.
12. Fuji T, Tsutsumi S, Matsumoto A, et al. Thickness of subcutaneous fat as a strong risk factor for wound infections in elective colorectal surgery: Impact of prediction using preoperative CT. Dig Surg. 2010;27(4):331-335. doi:10.1159/000297521.
13. Kozlow JH, Lisiecki J, Terijimanian MN, et al. Cross-sectional area of the abdomen predicts complication incidence in patients undergoing sternal reconstruction. J Surg Res. 2014;192(2):670-677. doi:10.1016/j.jss.2014.05.041.
14. Watts CD, Houdek MT, Wagner ER, Taunton MJ. Subcutaneous fat thickness is associated with early reoperation and infection after total knee arthroplasty in morbidly obese patients. J Arthroplasty. 2016;31(8):1788-1791. doi:10.1016/j.arth.2016.02.008.
15. Gupta A. The effectiveness of geriatrician-led comprehensive hip fracture collaborative care in a new acute hip unit based in a general hospital setting in the UK. J R Coll Physicians Edinb. 2014;44(1):20-26. doi:10.4997/JRCPE.2014.105.
16. Sprows GR, Allen BC, Wilson TJ, Pruszynski JE, Hammonds KAP. Predictive value of lateral soft tissue thickness for complications after total hip arthroplasty with a lateral incision. Proc (Bayl Univ Med Cent). 2020;33(3):336-341. doi:10.1080/08998280.2020.1753455.
17. Bell JA, Jeong A, Bohl DD, Levine B, Della Valle C, Nam D. Does peritrochanteric fat thickness increase the risk of early reoperation for infection or wound complications following total hip arthroplasty? J Orthop. 2019;16(5):359-362. doi:10.1016/j.jor.2019.03.025.
18. Marsh JL, Slongo TF, Agel J, et al. Fracture and dislocation classification compendium - 2007: Orthopaedic trauma association classification, database and outcomes committee. J Orthop Trauma. 2007;21(10 suppl I):S1-S133.
19. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis. 1987;40(5):373-383.
20. Quan H, Li B, Couris CM, et al. Updating and validating the Charlson comorbidity index and score for risk adjustment in hospital discharge abstracts using data from 6 countries. Am J Epidemiol. 2011;173(6):676-682. doi:10.1093/aje/kwq433.
21. Charlson M, Szatrowski TP, Peterson J, Gold J. Validation of a combined comorbidity index. J Clin Epidemiol. 1994;47(11):1245-1251.
22. Horan T, Gaynes R, Martone W, Jarvis W, Graceemori T. CDC definitions of nosocomial surgical site infections, 1992: A modification of CDC definitions of surgical wound infections. *Am J Infect Control*. 1992;20(5):271-274.

23. Mehta AI, Babu R, Sharma R, et al. Thickness of subcutaneous fat as a risk factor for infection in cervical spine fusion surgery. *J Bone Joint Surg Am*. 2013;95(4):323-328. doi:10.2106/JBJS.L.00225.

24. Mehta AI, Babu R, Karikari IO, Grunch B, Agarwal VJ, Owens TR, et al. 2012 young investigator award winner. *Spine*. 2012;37(19):1652-1656. doi:10.1097/BRS.0b013e318241b186.

25. Gupta VK, Kejriwal R. Pretubercular subcutaneous thickness is a protective factor for superficial wound complications after total knee arthroplasty in nonmorbidly obese patients. *J Arthroplasty*. 2020;35(1):255-258. doi:10.1016/j.arth.2019.08.046.

26. Toma O, Suntrup P, Stefanescu A, London A, Mutch M, Kharasch E. Pharmacokinetics and tissue penetration of cefoxitin in obesity. *Anesth Analg*. 2011;113(4):730-737. doi:10.1213/ANE.0b013e31821ff774.

27. Brill MJE, Houwink API, Schmidt S, et al. Reduced subcutaneous tissue distribution of cefazolin in morbidly obese versus non-obese patients determined using clinical microdialysis. *J Antimicrob Chemother*. 2014;69(3):715-723. doi:10.1093/jac/dkt444.

28. Aleem IS, Tan LA, Nasar A, Riew KD. Surgical site infection prevention following spine surgery. *Global Spine J*. 2020;10(1 suppl l):92S-98S. doi:10.1177/2192568219844228.

29. de Jong L, Klem TMAL, Kuiper TM, Roukema GR. Factors affecting the rate of surgical site infection in patients after hemiarthroplasty of the hip following a fracture of the neck of the femur. *Bone Joint J*. 2017;99-B(8):1088-1094. doi:10.1302/0301-620X.99B8.BJ-J-2016-1119.R1.

30. Liu X, Dong Z, Li J, et al. Factors affecting the incidence of surgical site infection after geriatric hip fracture surgery: A retrospective multicenter study. *J Orthop Surg Res*. 2019;14(1):382. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6873468/.

31. Daily JW, Yang HJ, Liu M, Kim MJ, Park S. Subcutaneous fat mass is associated with genetic risk scores related to proinflammatory cytokine signaling and interact with physical activity in middle-aged obese adults. *Nutr Metabol (Lond)*. 2019;16:75. doi:10.1186/s12986-019-0405-0.

32. Gleason LJ, Friedman SM. Preoperative management of anticoagulation and antiplatelet agents. *Clin Geriatr Med*. 2014;30(2):219-227. doi:10.1016/j.cger.2014.01.013.