The association between bone mineral density and postoperative drainage volume following primary total knee arthroplasty: a cross-sectional study

Yuthasak Peerakul  
Bamrasnaradura Infectious Diseases Institute

Jirapong Leeyaphan (lekortho@gmail.com)  
Bamrasnaradura Infectious Diseases Institute

Kam Rojjananukulpong  
Bamrasnaradura Infectious Diseases Institute

Research Article

Keywords: Total knee arthroplasty, Bone mineral density, Blood loss, Factor

DOI: https://doi.org/10.21203/rs.3.rs-140874/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

Background

The prevalence of osteoporosis in patients who undergo a primary total knee arthroplasty (TKA) is increasing. Low bone mineral density (BMD) is related to unfavorable outcomes following TKA such as migration of uncemented tibia components. Postoperative blood loss in TKA is an important complication. Non-modifying predicting factors for postoperative blood loss in primary TKA patients need further elucidation. Studies on the association between BMD and blood loss after TKA are limited. We aimed to demonstrate the relationship between BMD and postoperative drainage volume following primary TKA.

Method:

A cross-sectional study was conducted between January 2014 and August 2020. A total of 119 primary varus osteoarthritis knees with BMD results were included in the study. Patients with secondary causes for osteoporosis were excluded.

Result

The prevalence of osteopenia and osteoporosis diagnosed by the lowest T-score among two sites (hip and lumbar spine) were 55.5% and 28.6%, respectively. The median postoperative drainage volume of participants in the normal total hip BMD group and the normal trochanter BMD group was higher than that of patients in the low total hip BMD group and the low trochanter BMD group (285.0 ml vs. 230.0 ml, \( P = 0.003 \); 282.5 ml vs. 240.0 ml, \( P = 0.013 \), respectively). Multivariate regression analyses showed that operative time, spinal anesthesia, and normal total hip BMD status were significant predictive factors associated with increased postoperative drainage volume (\( P = 0.014, 0.022, 0.013 \), respectively). No association was identified between the lumbar spine BMD status and postoperative drainage volume.

Conclusion

The relationship between BMD and postoperative blood loss in primary TKA was identified in this study. Normal total hip BMD was found to be associated with an increased postoperative drainage volume after primary TKA compared with low BMD.

Background

Blood loss following total knee arthroplasty (TKA) is a common concern postoperative complication. The type of anesthesia used [1], type of surgery, operative time, body mass index (BMI) < 27 kg/m\(^2\) [2], prosthesis design, and postoperative anticoagulation drugs given [3] were found to predictive of
Postoperative blood loss after TKA. Despite the potential for some influencing factors to be reduced in the preoperative period, there are still many predisposing factors that cannot be preoperatively modified such as older age, sex, hypertension, presence of rheumatoid arthritis, and an American Society of Anesthesiologists (ASA) score > 3 [2]. Thus, many medication and methods have been investigated to reduce postoperative blood loss and blood transfusions, including tranexamic acid [4–7], computer assisted surgery [8–10], closed suction drainage [11, 12], no drainage [13], fibrin sealants [14], intramedullary femoral canal sealing [15], compression dressings [12], and a postoperative high-flexion knee position [16].

Osteoporosis is increasingly being found in patients who have undergone a primary TKA [17]. A previous study reported a prevalence of osteoporosis of 50.0% in patients awaiting TKA [18]. A low BMD was reported to be associated with unfavorable outcomes following TKA, such as the migration of uncemented tibia components [19]. The association between BMD and the volume of blood loss is controversial. A recent study showed an association between BMD and perioperative blood loss during mini-invasive posterior spinal fusion surgery. The patients who had low lumbar spine BMD tended to have more perioperative blood loss than those with normal BMD [20]. However, one study demonstrated no difference in the postoperative drainage volume after TKA in patients with rheumatoid arthritis, which is an osteoporosis risk factor [21], compared with normal cases with primary osteoarthritis [22]. An extensive literature review identified no previous reports on the relationship between BMD and postoperative blood loss in patients with primary TKA. This study aimed to clarify the association between BMD and the postoperative drainage volume following primary TKA. Moreover, risk factors for postoperative drainage volume were also identified and analyzed.

Methods

Study population

This cross-sectional study enrolled participants diagnosed with varus knee osteoarthritis who underwent primary TKA from January 2014 to August 2020. Patients who were diagnosed with causative disease for secondary osteoporosis were excluded from this study. The study protocol was approved by the institutional review board (S059h/63_ExPD).

Data collection

Data on age, sex, underlying hypertension, BMI, anesthesia, ASA score, preoperative hemoglobin content, preoperative platelet count, operative time, 24-hour postoperative mean arterial pressure (MAP), 24-hour postoperative blood loss drainage volume [23], BMD, and blood transfusion were collected and included in the analysis.

Dual-energy X-ray absorptiometry (DXA) was performed at two sites: the lumbar spine (L1-L4) and the hip (femoral neck, trochanter and total hip). All participants were assessed using the same DXA machine (Discovery Wi, Hologic, USA). The T-score interpretation used Asian/Japanese matched values. DXA
results were interpreted according to the World Health Organization criteria. T-scores of \( \leq -2.5 \) standard deviations (SD) below the reference mean were categorized as indicative of osteoporosis, T-scores between \(-1.0\) and \(-2.5\) SD as osteopenia, and T-scores \( \geq -1.0 \) SD as normal. In this study, patients with T-scores \(< -1.0 \) SD were categorized as having a low BMD, while those with T-scores \( \geq -1.0 \) SD were labeled as having a normal BMD.

**Surgical technique and postoperative management**

All TKAs were performed by a single surgeon to reduce the surgical technique bias. A tourniquet with a pressure of 300 mmHg was used in all cases. The surgeries were done after positioning. The lower extremity was prepared and draped with a standard method. The limb was elevated and exsanguinated with an elastic bandage. A straight midline skin incision was made, starting from 5 cm proximal to the superior pole of the patella and continuing to the medial side of the tibial tuberosity. A medial parapatellar arthrotomy was made, and then the medial soft tissue was released subperiosteally from the proximal medial part of the tibia to the posteromedial corner of the tibia. The patella was then everted after releasing the patellofemoral ligament. The anterior and posterior cruciate ligaments were released. The medial and lateral meniscus were excised, and then the proximal portion of the tibia was resected at 90 degrees to its long axis with an intramedullary tibial guide. The distal femur was resected at 5 degrees valgus with an intramedullary femoral guide. The selective patella was then prepared for resurfacing. Anterior, posterior, chamfer, and box cuts were made. The trial components were placed to test the knee for stability and for adequate patellar tracking. The knee was irrigated with 1000 ml of normal saline, and the bone was dried. The components (New wave\textsuperscript{TM}, Groupe Lépine, Genay, France) were cemented into place. Two grams of tranexamic acid was intra-articular injected and left for 5 minutes. The drain was placed, and then the quadriceps tendon and joint capsule was repaired with an interrupted absorbable suture (number 1). The skin was closed with absorbable subcuticular running sutures (number 3/0). The knee was dressed in gauze without a bandage. The tourniquet was deflated, and then the drain was released. All patients received patient-controlled analgesia for 48 hours without postoperative deep vein thrombosis prophylaxis. The drain was removed at 24 hours post-operation.

**Statistical Analysis**

A sample size calculation was performed by using G*Power 3.1 software (University of Dusseldorf, Dusseldorf, Germany) \[24\], which determined that a minimum of 118 participants was required with an effect size of 0.15 to achieve a statistical power \( \geq 80 \) at P-value \( \alpha \) levels of \( \leq 0.05 \) and for 10 predictors. Descriptive analyses such as mean values with standard deviations, medians with the 25\textsuperscript{th}-75\textsuperscript{th} percentile ranges, or counts were performed. Independent sample t-tests were used to compare means of normally distributed data, and the Mann–Whitney U test was used for non-normally distributed continuous variables. A univariate regression analysis was performed to estimate the relationships among variables and the postoperative drainage volume. In terms of qualitative variables, for sex, male was set as “1” and female was set as “0”. For hypertension, yes was set as “1” and no was set as “0”. For anesthesia, spinal anesthesia was set as “1” and general anesthesia was set as “0”. For BMD status, low was set as “1” and
normal was set as “0”. The variables with $P$-values of less than 0.25 in the univariate regression analysis or other variables of known clinical relevance were included for further multivariate regression analysis [25]. All data were analyzed using Statistical Package for the Social Sciences for Windows 26.0 (Armonk, NY, USA). A $P$-value of <0.05 was considered statistically significant.

**Results**

A total of 119 participants diagnosed with primary varus knee osteoarthritis were included in the study (Fig. 1). The prevalence of osteopenia and osteoporosis diagnosed by the lowest T-score was 55.5% (n = 66) and 28.6% (n = 34), respectively. The clinical characteristics of the study population are shown in Table 1. The median postoperative drainage volume of participants in the normal total hip BMD group and the normal trochanter BMD group was higher than that in the low total hip BMD group and the low trochanter BMD group ($P = 0.003$, $P = 0.013$, respectively) (Table 2, Fig. 2).
| Clinical characteristics | Normal BMD \((n=19)\) | Low BMD \((n=100)\) | \(P\) Value |
|--------------------------|-----------------------|---------------------|------------|
| Age (years)              | 72.79 ± 6.55          | 73.24 ± 5.73        | 0.760      |
| Sex                      | 15                    | 95                  | 0.035      |
| Male                     | 4                     | 5                   |            |
| BMI (kg/m\(^2\))        | 28.98 ± 4.93          | 26.40 ± 3.83        | 0.012      |
| Anesthesia               | 13                    | 70                  | 0.891      |
| Spinal anesthesia        | 6                     | 30                  |            |
| General anesthesia       |                       |                     |            |
| ASA score                | 9                     | 33                  | 0.230      |
| 2                        | 10                    | 67                  |            |
| 3                        |                       |                     |            |
| Hypertension             | 14                    | 83                  | 0.338      |
| Yes                      | 5                     | 17                  |            |
| No                       |                       |                     |            |
| Operative time (min)     | 105.5 ± 8.2           | 99.8 ± 9.1          | 0.014      |
| Blood transfusion        | 0                     | 3                   | 0.444      |
| Yes                      | 19                    | 97                  |            |
| No                       |                       |                     |            |
| Postoperative MAP (mmHg) | 102.4 ± 9.6           | 95.0 ± 9.6          | 0.003      |
| Drainage volume (ml)     | 271.6 ± 84.0          | 281.2 ± 148.5       | 0.786      |

**Laboratory parameters**

| Variable                  | Normal BMD \((g/mm^3)\) | Low BMD \((g/mm^3)\) | \(P\) Value |
|---------------------------|--------------------------|----------------------|-------------|
| Hemoglobin \((g/mm^3)\)   | 12.4 ± 0.9               | 12.1 ± 1.3           | 0.362       |
| Hematocrit (%)            | 38.2 ± 3.0               | 37.2 ± 3.6           | 0.274       |
| Platelet \((\times10^3/mm^3)\) | 270.6 ± 102.5          | 252.0 ± 53.2         | 0.242       |

**Bone mineral density**

Variables are presented as mean ± standard deviation or number (count).
## Clinical characteristics

|                  | Normal BMD ($n = 19$) | Low BMD ($n = 100$) | $P$ Value |
|------------------|-----------------------|---------------------|-----------|
| Lumbar spine T-score | $0.53 \pm 0.78$       | $-1.19 \pm 1.15$   | $< 0.001$ |
| Trochanter T-score  | $0.41 \pm 0.79$       | $-1.14 \pm 0.75$   | $< 0.001$ |
| Femoral neck T-score | $-0.16 \pm 0.84$     | $-2.08 \pm 0.70$   | $< 0.001$ |
| Total hip T-score   | $0.59 \pm 0.77$       | $-1.11 \pm 0.79$   | $< 0.001$ |

Variables are presented as mean $\pm$ standard deviation or number (count).

### Table 2

**Comparison between postoperative drainage volume (ml) with BMD site and bone status**

| Sites          | Normal BMD ($n = 56$) | Low BMD ($n = 57$) | $P$ Value |
|----------------|-----------------------|---------------------|-----------|
| Lumbar spine   | $245.0$ (172.5, 330.0) | $270.0$ (190.0, 350.0)   | 0.836     |
| Trochanter     | $282.5$ (217.5, 410.0) | $240.0$ (160.0, 320.0)  | 0.013     |
| Femoral neck   | $260.0$ (217.5, 376.3) | $270.0$ (175.0, 340.0)  | 0.549     |
| Total hip      | $285.0$ (215.0, 410.0) | $230.0$ (150.0, 305.0)  | 0.003     |

Variables are presented as medians (the 25th percentile, the 75th percentile).

The univariate regression analyses showed significant associations of the operative time, trochanter BMD status, and total hip BMD status with the postoperative drainage volume (all $P < 0.05$) (Table 3). No relationships were identified between the postoperative drainage volume and femoral neck BMD status or lumbar spine BMD status.
A multivariate regression analysis was used to correct for operative time, trochanter BMD status, and total hip BMD status, which were identified as significant independent factors in the univariate regression analysis. Age, sex, BMI, hypertension, and anesthesia were analyzed in the model because of their clinical relevance to postoperative blood loss. Femoral neck BMD status, trochanter BMD status, and total hip BMD status were analyzed in a separate model due to multicollinearity problems. The multivariate analysis using total hip BMD status showed that spinal anesthesia, the operative time, and the total hip BMD status were significantly associated with the postoperative drainage volume ($P = 0.022$, $0.014$ and $0.013$, respectively). However, the multivariate regression analysis using the femoral neck BMD status and trochanter BMD status model found that neither femoral neck BMD status or trochanter BMD status were related to the postoperative drainage volume ($P = 0.853$ and $P = 0.109$, respectively) (Table 4).
Table 4
Multivariate regression analysis of the relationships between variables and the postoperative drainage volume

| Variables                                      | β(SE)     | t      | P       | VIF  |
|------------------------------------------------|-----------|--------|---------|------|
| Total hip status (R square = 0.449, Adjusted R square = 0.202) |           |        |         |      |
| Anesthesia (SA vs GA)                          | 0.218(28.317) | 2.328  | 0.022   | 1.105|
| Operative time (min)                           | 0.269(1.582)  | 2.514  | 0.014   | 1.447|
| Lumbar spine status (normal vs low)           | 0.103(27.191) | 1.030  | 0.306   | 1.254|
| Total hip status (normal vs low)              | -0.272(29.815) | -2.530 | 0.013   | 1.465|
| Trochanter status (R square = 0.415, Adjusted R square = 0.173) |           |        |         |      |
| Anesthesia (SA vs GA)                          | 0.211(28.960) | 2.210  | 0.029   | 1.115|
| Operative time (min)                           | 0.311(1.580)  | 2.914  | 0.004   | 1.392|
| Lumbar spine status (normal vs low)           | 0.052(26.722) | 0.534  | 0.595   | 1.169|
| Trochanter status (normal vs low)             | -0.170(28.697) | -1.617 | 0.109   | 1.348|
| Femoral neck status (R square = 0.389, Adjusted R square = 0.151) |           |        |         |      |
| Anesthesia (SA vs GA)                          | 0.227(29.177) | 2.354  | 0.020   | 1.103|
| Operative time (min)                           | 0.362(1.561)  | 3.432  | 0.001   | 1.325|
| Lumbar spine status (normal vs low)           | 0.017(27.473) | 0.165  | 0.869   | 1.204|
| Femoral neck status (normal vs low)           | 0.020(37.517)  | 0.186  | 0.853   | 1.360|

All models were adjusted for age, sex, body mass index, postoperative mean arterial pressure, hemoglobin, and platelets.

Discussion

Postoperative blood loss after TKA is derived from bone and soft tissue, and we could not determine which component generated greater blood loss. Low BMD related to osteoporosis is a common skeletal disorder which is characterized by small bone size and disrupted macro- and micro- architectures [26]. This study demonstrated an association between BMD and the postoperative drainage volume following primary TKA. Participants with a normal total hip BMD had a greater postoperative drainage volume than those with a low total hip BMD. The results of this study showed the linkage of bone quality with postoperative blood loss after primary TKA. The vascular supply in the lower extremities was proposed as a reason for this finding, as a low vascular supply may cause a low total hip BMD and low blood loss during surgery. The linkage between the peripheral vascular supply and BMD has been identified by many previous reports [27–30]. Changes in the hip bone mineral density are associated with blood flow to the
lower extremities. Decreased BMD at the hip and calcaneus is associated with decreased vascular flow to the lower extremities in healthy, older women [31]. Thus, this low blood supply may cause a low BMD and reduce blood loss post-TKA. However, to determine the exact pathogenesis of this result, further study is required.

Previous studies reported that large blood sinusoids in trabecular bone are commonly found in osteoporosis patients and lead to increased bleeding during spinal surgery. Patients with low BMD in the spine were found to have greater perioperative blood loss than those with normal BMD in the spine (357.2 ml vs 259.4 ml) during spinal fusion surgery [20]. On the other hand, lumbar spine BMD status was not found to be associated with the postoperative drainage volume following TKA in this study. The local bone architecture and local soft tissue blood supply may be important factors in blood loss. Hip BMD may be correlated more closely with the bone architecture around the knee joints than the spine, so only hip BMD was associated with blood loss after TKA. Moreover, spinal surgery and TKA use different bleeding control techniques. In this study, a tourniquet was used to reduce the local soft tissue blood supply and may have played an essential role in controlling bleeding. In addition, use of a tourniquet and covering of the surface of bone cut with prosthesis were applied in TKA to decrease blood loss during the operation.

Additionally, this study showed that spinal anesthesia and the operating time were predictive factors associated with an increased postoperative drainage volume in primary TKA. A previous study demonstrated an association between blood loss and type of anesthesia [1]. Similarly, this study supported the finding that regional anesthesia is significantly associated with blood loss in primary TKA. According to the operative time, a previous study reported that a longer surgery time is associated with a greater blood transfusion requirement [32]. This study also supported the idea that an increased operative time results in a greater postoperative drainage volume.

This study has several limitations. Firstly, there were missing data, such as blood coagulation results, and bias could have existed due to the retrospective nature of the study. Moreover, data on the severity of knee osteoarthritis were not collected, and this could have been a confounding factor. Severe osteoarthritis cases may require more soft tissue release and might produce more blood loss. Secondly, BMD was not directly measured from the distal femur and proximal tibia around the knee joint. However, a previous study reported positive correlations among the distal femur BMD, proximal tibia BMD, and central BMD [33]. The distal femur BMD and proximal tibia BMD should be analyzed to determine their correlations with post-TKA blood loss. Thirdly, the 24-hour postoperative drainage volume was included in this analysis. Hidden blood loss may yield a greater volume than visible blood loss [34].

**Conclusion**

This study demonstrated the correlation between BMD and postoperative drainage volume following primary TKA. Patients with a normal total hip BMD status had greater blood loss than those with a low total hip BMD status.
Abbreviations

TKA: total knee arthroplasty; BMD: bone mineral density; BMI: body mass index; ASA: American Society of Anesthesiologists; MAP: mean arterial pressure; β: standardized coefficient; DXA: Dual-energy X-ray absorptiometry; SD: standard deviation; SE: standard error; t: corresponding t values; R²: percent variance explained by each variable; VIF: variance inflation factor; SA: spinal anesthesia; GA: general anesthesia.

Declarations

Acknowledgements

We acknowledge Apichart Vachiraphan, Director of Bamrasnaradura Infectious Diseases Institute, Department of Disease Control, Ministry of Public Health, Nonthaburi, Thailand, for administrative support.

Authors’ contributions

Y P: Study design, collected the data, and manuscript writing; J L: Analyzed and interpreted the patient data, manuscript writing; K R: Manuscript writing. All authors read and approved the final manuscript.

Funding

This research received no external funding.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics declarations

The study protocol was approved by Institutional Review Board of the Bamrasnaradura Infectious Diseases Institute (S059h/63_ExPD) and was conducted in compliance with the ethical principles of the Helsinki Declaration of 1975. Informed consent was waived by the institutional review board which approved the study. All methods were carried out in accordance with the STROBE guidelines for cross-sectional studies.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.
References

1. Zhu M, Chen JY, Tan YR, Yew AK, Chong HC, Chia SL, et al. Effects of anesthetic technique on blood loss and complications after simultaneous bilateral total knee arthroplasty. Arch Orthop Trauma Surg. 2015;135(4):565-71.

2. Sizer SC, Cherian JJ, Elmallah RD, Pierce TP, Beaver WB, Mont MA. Predicting Blood Loss in Total Knee and Hip Arthroplasty. Orthop Clin North Am. 2015;46(4):445-59.

3. Hu Y, Li Q, Wei BG, Zhang XS, Torsha TT, Xiao J, et al. Blood loss of total knee arthroplasty in osteoarthritis: an analysis of influential factors. J Orthop Surg Res. 2018;13(1):325.

4. Gandhi R, Evans HM, Mahomed SR, Mahomed NN. Tranexamic acid and the reduction of blood loss in total knee and hip arthroplasty: a meta-analysis. BMC Res Notes. 2013;6:184.

5. Yang ZG, Chen WP, Wu LD. Effectiveness and safety of tranexamic acid in reducing blood loss in total knee arthroplasty: a meta-analysis. J Bone Joint Surg Am. 2012;94(13):1153-9.

6. Wu YG, Zeng Y, Hu QS, Bao XC, Xiong HZ, Shen B. Tranexamic Acid Plus Low-dose Epinephrine Reduces Blood Loss in Total Knee Arthroplasty: A Systematic Review and Meta-analysis. Orthop Surg. 2018;10(4):287-95.

7. Zhang H, Chen J, Chen F, Que W. The effect of tranexamic acid on blood loss and use of blood products in total knee arthroplasty: a meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2012;20(9):1742-52.

8. Hinarejos P, Corrales M, Matamalas A, Bisbe E, Caceres E. Computer-assisted surgery can reduce blood loss after total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc. 2009;17(4):356-60.

9. Han SB, Kim HJ, Kim TK, In Y, Oh KJ, Koh IJ, et al. Computer navigation is effective in reducing blood loss but has no effect on transfusion requirement following primary total knee arthroplasty: a meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2016;24(11):3474-81.

10. Licini DJ, Meneghini RM. Modern abbreviated computer navigation of the femur reduces blood loss in total knee arthroplasty. J Arthroplasty. 2015;30(10):1729-32.

11. Tsumara N, Yoshiya S, Chin T, Shiba R, Kohso K, Doita M. A prospective comparison of clamping the drain or post-operative salvage of blood in reducing blood loss after total knee arthroplasty. J Bone Joint Surg Br. 2006;88(1):49-53.

12. Banerjee S, Kapadia BH, Issa K, McElroy MJ, Khanuja HS, Harwin SF, et al. Postoperative blood loss prevention in total knee arthroplasty. J Knee Surg. 2013;26(6):395-400.

13. Wang CG, Sun ZH, Liu J, Cao JG, Li ZJ. Safety and efficacy of intra-articular tranexamic acid injection without drainage on blood loss in total knee arthroplasty: A randomized clinical trial. Int J Surg. 2015;20:1-7.

14. Li ZJ, Fu X, Tian P, Liu WX, Li YM, Zheng YF, et al. Fibrin sealant before wound closure in total knee arthroplasty reduced blood loss: a meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2015;23(7):2019-25.
15. Wang K, Yuan W, An J, Cheng P, Song P, Li S, et al. Sealing the Intramedullary Femoral Canal for Blood Loss in Total Knee Arthroplasty: A Meta-analysis of Randomized Controlled Trials. J Knee Surg. 2019.

16. Wu Y, Yang T, Zeng Y, Si H, Li C, Shen B. Effect of different postoperative limb positions on blood loss and range of motion in total knee arthroplasty: An updated meta-analysis of randomized controlled trials. Int J Surg. 2017;37:15-23.

17. Bernatz JT, Krueger DC, Squire MW, Illgen RL, 2nd, Binkley NC, Anderson PA. Unrecognized Osteoporosis Is Common in Patients With a Well-Functioning Total Knee Arthroplasty. J Arthroplasty. 2019;34(10):2347-50.

18. Ha CW, Park YB. Underestimation and undertreatment of osteoporosis in patients awaiting primary total knee arthroplasty. Arch Orthop Trauma Surg. 2020;140(8):1109-14.

19. Andersen MR, Winther NS, Lind T, Schroder HM, Flivik G, Petersen MM. Low Preoperative BMD Is Related to High Migration of Tibia Components in Uncemented TKA-92 Patients in a Combined DEXA and RSA Study With 2-Year Follow-Up. J Arthroplasty. 2017;32(7):2141-6.

20. He Y, Liu C, Huang Y. Can bone mineral density affect intra-operative blood loss of mini-invasive posterior lumbar interbody fusion? Endosc Robot Surg. 2020;3(3):66-9.

21. Xue AL, Wu SY, Jiang L, Feng AM, Guo HF, Zhao P. Bone fracture risk in patients with rheumatoid arthritis: A meta-analysis. Medicine (Baltimore). 2017;96(36):e6983.

22. Prasad N, Padmanabhan V, Mullaji A. Blood loss in total knee arthroplasty: an analysis of risk factors. Int Orthop. 2007;31(1):39-44.

23. Magill P, Cunningham EL, Hill JC, Beverland DE. Identifying the period of greatest blood loss after lower limb arthroplasty. Arthroplasty Today. 2018;4(4):499-504.

24. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007;39(2):175-91.

25. Mickey RM, Greenland S. The impact of confounder selection criteria on effect estimation. Am J Epidemiol. 1989;129(1):125-37.

26. Choksi P, Jepsen KJ, Clines GA. The challenges of diagnosing osteoporosis and the limitations of currently available tools. Clin Diabetes Endocrinol. 2018;4(4):12.

27. Mangiafico RA, Russo E, Riccobene S, Pennisi P, Mangiafico M, D’Amico F, et al. Increased prevalence of peripheral arterial disease in osteoporotic postmenopausal women. J Bone Miner Metab. 2006;24(2):125-31.

28. von Muhlen D, Allison M, Jassal SK, Barrett-Connor E. Peripheral arterial disease and osteoporosis in older adults: the Rancho Bernardo Study. Osteoporos Int. 2009;20(12):2071-8.

29. Collins TC, Ewing SK, Diem SJ, Taylor BC, Orwell ES, Cummings SR, et al. Peripheral arterial disease is associated with higher rates of hip bone loss and increased fracture risk in older men. Circulation. 2009;119(17):2305-12.
30. Tanko LB, Bagger YZ, Christiansen C. Low bone mineral density in the hip as a marker of advanced atherosclerosis in elderly women. Calcif Tissue Int. 2003;73(1):15-20.

31. Vogt MT, Cauley JA, Kuller LH, Nevitt MC. Bone mineral density and blood flow to the lower extremities: the study of osteoporotic fractures. J Bone Miner Res. 1997;12(2):283-9.

32. Noticewala MS, Nyce JD, Wang W, Geller JA, Macaulay W. Predicting need for allogeneic transfusion after total knee arthroplasty. J Arthroplasty. 2012;27(6):961-7.

33. Beattie KA, Boulos P, Duryea J, O'Neill J, Pui M, Gordon CL, et al. The relationships between bone mineral density in the spine, hip, distal femur and proximal tibia and medial minimum joint space width in the knees of healthy females. Osteoarthritis Cartilage. 2005;13(10):872-8.

34. Sehat KR, Evans RL, Newman JH. Hidden blood loss following hip and knee arthroplasty. Correct management of blood loss should take hidden loss into account. J Bone Joint Surg Br. 2004;86(4):561-5.

**Figures**

![Flowchart for subject enrollment.](image-url)

- **Primary total knee arthroplasty from January 2014 to August 2020 n = 427**
  - Excluded for different prosthesis design n = 22

- **Primary total knee arthroplasty, single prosthesis design n = 405**
  - Excluded for lack of BMD result n = 286
  - Presence of chronic liver or kidney diseases n = 0

- **Primary total knee arthroplasty, single prosthesis design with BMD result n = 119**

**Figure 1**

Flowchart for subject enrollment.
Figure 2

Box plots of 24-hour postoperative drainage volume and BMD status. Outliers are indicated by circles.