Therapeutics and Clinical Risk Management

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Establishment and Verification of Risk Prediction Model for Adverse Outcomes After Hip Arthroplasty in Elderly Patients

Jie Ding[1], Guoli Sun[2], Yifei Ren[1], Jiajia Xu[1], Qingqing Hu[1], Jun Luo[1], Zhaowen Wu[1], Ting Chu[1]

[1]School of Nursing, Zhejiang Chinese Medical University, Hangzhou, Zhejiang Province, 310053, People's Republic of China; [2]Department of Orthopaedics, The Second Affiliated Hospital of Zhejiang Chinese Medical University, Hangzhou, Zhejiang Province, 310053, People's Republic of China

Correspondence: Ting Chu, School of Nursing, Zhejiang Chinese Medical University, 548 Binwen Road, Binjiang District, Hangzhou, Zhejiang Province, 310053, People's Republic of China, Tel +8618357122767, Email chut@zcmu.edu.cn

Background: Adverse outcomes after hip arthroplasty in elderly patients are frequently observed; however, most existing studies concentrate on single complications. Comprehensive predictive models for a wider range of adverse outcomes remain insufficient. This study explores this issue and proposes new approaches for clinical practice.

Purpose: This study aimed to construct and verify risk prediction model for adverse outcomes after hip arthroplasty in elderly patients.

Patients and Methods: The TRIPOD checklist was followed to guide the reporting of this study. Data from 620 subjects who underwent hip arthroplasty at a tertiary A-level hospital from January 1, 2021 to December 31, 2023 were used for the modelling group. Additionally, 264 post-hip arthroplasty patients admitted to the orthopaedic department of another tertiary A-level hospital from January 1, 2024 to December 31, 2024 were selected as the validation group. Risk prediction models were constructed by logistic regression, plotted in column line graphs and evaluated for their predictive effectiveness.

Results: The factors included in the prediction model were age, malignancy history, surgical procedure, albumin, prothrombin time, ASA grade, operation duration, and changeover surgery status. Hosmer-Lemeshow test, $\chi 2$=5.418, p=0.712, the area under the receiver operating characteristic curve (AUC) was 0.902. The Youden index is 0.668, with a sensitivity of 0.84 and a specificity of 0.828. The correct practical application rate was 83.33%.

Conclusion: The risk prediction model constructed in this study demonstrates favourable predictive performance and can serve as a reference for healthcare professionals in predicting the risk of adverse outcomes after hip arthroplasty in elderly patients.

Keywords: Hip arthroplasty, aged, nomograms, forecasting, risk

Introduction

Hip arthroplasty stands as a key surgical intervention for end-stage hip diseases, frequently employed for conditions like osteoarthritis, osteonecrosis of the femoral head, hip dysplasia, and hip fractures.[1] The ageing population and technological advancements have led to a consistent annual increase in hip arthroplasty procedures, with a particularly notable rise among elderly patients.[2] This group, characterized by distinct physiological traits and disease profiles, is more prone to adverse outcomes following surgery.[3] Elderly patients frequently have multiple comorbidities, such as cardiovascular disease, diabetes, and osteoporosis, which markedly increase the risk of adverse postoperative outcomes.[4] As ageing progresses, their physiological and functional reserves decline, along with a significant reduction in immune function, resulting in decreased tolerance to surgical trauma. This predisposition raises the likelihood of severe complications, including infection, deep vein thrombosis, and cardiovascular events.[5] Moreover, diminished postoperative rehabilitation capacity, coupled with insufficient social and psychological support, further obstructs the functional recovery of elderly patients and adversely affects their long-term prognosis.[6] Elderly patients are at a significantly higher risk of

Received: 26 February 2025
Accepted: 29 June 2025
Published: 10 July 2025

complications following hip arthroplasty than the general population, with studies reporting incidence rates of up to 20% to 40%.[5] These complications considerably extend hospital stays, escalate healthcare costs, and heighten the risk of postoperative mortality.[7] Furthermore, complications can cause delays in recovery, lower quality of life, and long-term negative impacts on physical and mental health.[8] Therefore, preventing postoperative complications is essential for optimal postoperative management. A precise and practical risk assessment of complications in surgical patients is a critical step in implementing effective interventions.[9]

Research indicates a strong correlation between postoperative complications and factors such as demographics, comorbidities, and substance use.[10] When combined, these factors may help predict the risk of postoperative complications.[11,12] The findings of Tanaka et al demonstrate that muscle strength (assessed via grip strength monitoring) and physical performance (evaluated through gait speed measurement) serve as valid indicators for evaluating functional recovery after hip arthroplasty.[13] Several risk prediction models for surgical complications have been developed for preoperative counselling in first-time hip arthroplasty patients,[14–18] but only a limited number of studies have externally validated these models.[19,20] External validation is essential to evaluate the generalizability of predictive models, as differences in patient demographics and healthcare environments can significantly influence model performance.[21] Research has shown that models for predicting complications after hip arthroplasty often lack sufficient predictive accuracy in new patient groups and varying healthcare settings, limiting their clinical utility.[13,20] This inadequacy underscores the necessity of creating more accurate, robust, and generalizable risk prediction tools for patients undergoing hip arthroplasty.

Significant progress has been made in predicting the risk of complications after hip arthroplasty. For instance, risk prediction models have been developed for specific complications, such as deep vein thrombosis (DVT),[22,23] postoperative infection,[24,25] and dislocation.[26,27] Much of the current research centres on postoperative complications, with comparatively less exploration of broader adverse outcomes, such as extended hospital stays, ICU admissions, and mortality, presenting considerable opportunities for innovation in this field.[28,29] This gap may result in insufficient assessment of overall patient risk, potentially compromising the comprehensiveness of clinical decision-making.[26] Investigating adverse postoperative outcomes, rather than isolated complications, allows for a more holistic evaluation of patient risk and offers a scientific basis for developing individualized perioperative interventions.[30] Thus, it is necessary to explore risk factors associated with adverse outcomes post-hip arthroplasty and establish predictive models.

Material and Methods

The TRIPOD checklist was followed to guide the reporting of this study.

Study Design and Participants

This case-control study retrospectively included patients who underwent hip arthroplasty in the Department of Orthopaedics at a tertiary hospital in Zhejiang Province from January 1, 2021 to December 31, 2023. During or after data collection, the authors could obtain information that could identify individual participants from January 1, 2021 to December 31, 2023.

There were 620 cases in the modelling group. The inclusion criteria were: (1) age $\geq$ 65 years; (2) meeting the indications for hip arthroplasty and being a first-time unilateral hip arthroplasty recipient; (3) no significant adverse events before admission, such as shock, altered consciousness, acute respiratory failure, or acute heart failure. The exclusion criteria were: (1) patients diagnosed with deep vein thrombosis (DVT) or pulmonary embolism (PE) before surgery or with embolism at other arterial or venous sites; (2) those with severe vital organ dysfunction; (3) patients with mental disorders; (4) patients with incomplete or missing medical records, laboratory data, or imaging results. The enrolled cases were divided into the No Adverse Outcomes Group and the Adverse Outcomes Group, based on whether patients experienced adverse outcomes. Adverse outcomes were defined as at least one of the following: surgical site infection, deep vein thrombosis (DVT), pulmonary embolism, prolonged hospital stay, transfer to the intensive care unit (ICU), or all-cause mortality. The sample size was calculated using the event/variable method (EPV),[31] suggesting that the prediction model's sample size should be 10 to 20 times the number of predictors. This study included 33 predictors, requiring a sample size of 330 to 660 cases. In total, 620 hospitalized elderly patients were included in the survey, with

212 in the Adverse Outcomes group and 408 in the No Adverse Outcomes group. The selection of patients in the modeling group is shown in Figure 1.

Additionally, 264 post-hip arthroplasty patients from another tertiary care hospital's orthopaedic department were selected as the external validation group between January 1, 2024 and December 31, 2024.[32] During or after data collection, the authors could obtain information that could identify individual participants from January 1, 2024 to December 31, 2024.

Candidate Predictors

In this study, following a literature review, nine orthopaedic physicians and six orthopaedic specialist nurses, each with intermediate or higher professional titles, were invited to provide expert evidence.[33] This collaborative effort led to the establishment of 33 candidate predictors for adverse outcomes, categorized as (1) Demographic data: age, sexuality, BMI; (2) Patient history: smoking, drinking, hypertension, diabetes, craniocerebral disease, cardiac disease, malignancy, osteoporosis; (3) laboratory indexes: red blood cell (RBC), haemoglobin (HB), platelets (PLT), albumin (ALB), C-reactive protein (CRP), glutamate aminotransferase (ALT), glutamate oxaloacetate transaminase (AST), direct bilirubin (DBil), indirect bilirubin (IBil), international normalized ratio (INR), D-dimer (D-D), prothrombin time (PT), activated partial thromboplastin time (APTT); (4) Surgical factors: surgical procedure, type of anaesthesia, ASA grade, operation duration, intraoperative blood loss, intraoperative blood transfusion, changeover surgery status (consecutive hip arthroplasty procedures performed by the same surgical team within a turnover interval ≤30 minutes); and (5) postoperative indicators: postoperative pain scores and the use of drains.

Adverse Outcomes

Adverse outcomes include surgical site infection, deep vein thrombosis (DVT), pulmonary embolism, prolonged hospital stay, ICU transfer, and in-hospital death.[34,35] Variations in surgical procedures and care across regions, patient populations, and healthcare settings have led to differing definitions of prolonged length of stay (PLOS).[6,36] In this study, PLOS is defined as the 75th percentile of length of stay among all patients, which is 22 days.[37] In-hospital death is defined as all-cause death during hospitalization, while ICU transfer is defined as any transfer (including injury-related).[38]

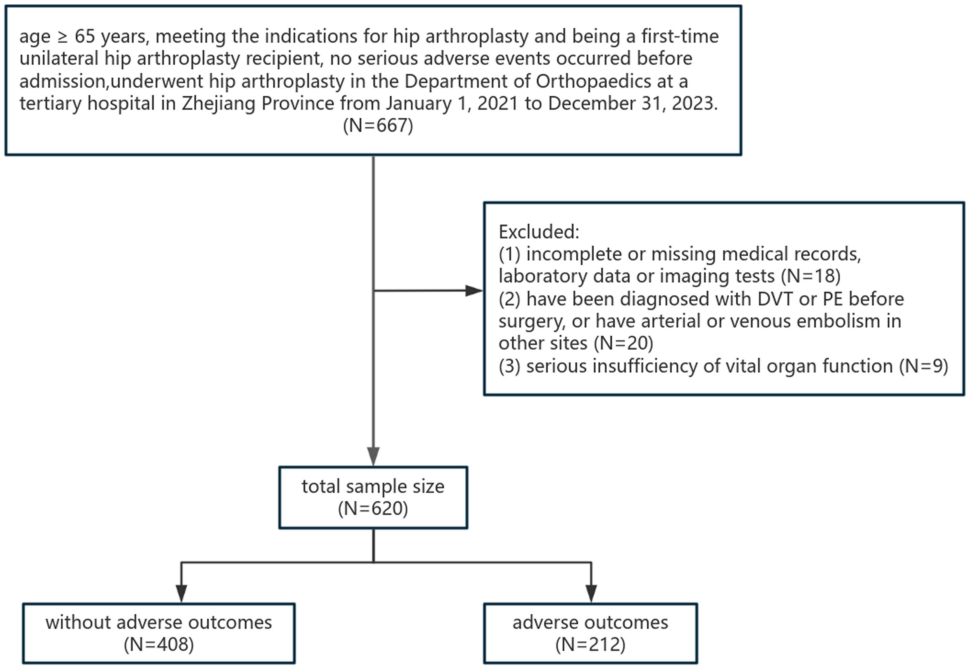

Figure 1 Flowchart of patient selection.

https://doi.org/10.2147/TCRM.S523040

Data Collection

The five researchers responsible for data collection from the electronic case system received standardized data collection training from the project leader. The researchers subsequently retrieved demographic data, patient history, laboratory indexes, surgical factors, and postoperative indicators from the hospital's electronic medical record system and documented them on a pre-designed form. The data were further reviewed by another researcher to identify missing items, duplicates, and other anomalies, ensuring the completeness and accuracy of the information.

Ethical Considerations

Approval for the study was granted by the Ethics Committee (reference number: 20241025–4). As the study was retrospective and posed minimal risk to participants, the requirement for mandatory informed consent was waived.

Statistical Methods

Statistical analysis was conducted using SPSS (version 25.0, IBM Corporation, USA) and R (version 4.2.2, R Foundation for Statistical Computing). The Shapiro–Wilk (SW) test was performed to assess normality distribution. For count data, frequency and percentage were calculated, and the chi-square test was applied for intergroup comparisons. Normally distributed measurement data were presented as mean±standard deviation, and the *t*-test was used for intergroup comparisons. Non-normally distributed measurement data were described by the median and interquartile range, with the rank-sum test used for intergroup comparisons. Multifactorial logistic regression was then performed to construct the prediction model. The receiver operating characteristic (ROC) curve was plotted, and the area under the curve (AUC) was calculated to evaluate the model's discriminatory ability. The calibration of the model was assessed using the Hosmer-Lemeshow test. Finally, the practical applicability of the model was evaluated by calculating sensitivity, specificity, and accuracy using clinical application data.

Results

Demographic Data

A total of 884 valid cases were collected, including 620 in the modelling and 264 in the validation groups. In the modelling group, there were 264 males (42.58%) and 356 females (57.42%); aged 65–98 (74.79 SD 7.39) years. In the validation group, there were 108 males (40.91%) and 156 females (59.09%); aged 65–95 (74.37 SD 6.32) years.

Single-Factor Analysis of Postoperative Adverse Outcomes in Model Group

The 620 patients in the modelling group were divided into the no adverse outcomes group and the adverse outcomes group, with 212 cases in the adverse outcomes group and the incidence of adverse outcomes was 34.19%. After single factor analysis, 21 variables were statistically significant ($p < 0.05$). Those 21 variables included age, smoking, hypertension, diabetes, craniocerebral disease, cardiac disease, malignancy, surgical procedure, HB, ALB, ALT, CRP, D-dimer, PT, APTT, INR, ASA grade, operation duration, intraoperative blood loss, intraoperative blood transfusion, changeover surgery status. The results of the univariate analysis are presented in Table 1. The 21 identified influencing factors were subjected to multicollinearity diagnostics, revealing that the variance inflation factor (VIF) values ranged from 1.044 to 1.423, and tolerance values ranged from 0.703 to 0.958, indicating the absence of multicollinearity among the variables.

Prediction Model of Adverse Outcomes Risk After Hip Arthroplasty

Twenty-one variables with statistical significance mentioned above were subjected to binary logistic regression. The results showed that age, malignancy history, surgical procedure, ALB, PT, ASA grade, operation duration and changeover surgery status were associated with adverse outcomes, as shown in Table 2. The model was constructed as follows: logistic (P) = 0.692 + 0.056× age + 1.200×1(malignancy history) - 0.749×1(surgical procedure) - 0.350×ALB + 0.169×PT + 2.036×1(ASA grade) + 0.041×operation duration + 0.927×1(changeover surgery status). The visualised column line graph is plotted in Figure 2.

Table 1 Risk Factors of Postoperative Adverse Outcomes and Univariate Analysis Results (n = 620)

Independent Variable	Adverse Outcomes group (n=212)	No Adverse Outcomes Group (n=408)	Statistic value	*P*
Sexuality			1.550[a]	0.213
Male	83(39.2%)	181(44.4%)		
Female	129(60.8%)	227(55.6%)		
Age(y)	78.0(70.0,81.0)	71.0(68.0,77.0)	−5.685[c]	<0.001
BMI(kg/m^2))	20.20(19.13,22.96)	19.85(18.50,22.55)	−1.771[c]	0.077
Smoking			10.998[a]	0.001
Yes	49(23.1%)	52(12.7%)		
No	163(76.9%)	356(87.3%)		
Drinking			0.066[a]	0.797
Yes	26(12.3%)	53(13.0%)		
No	186(87.7%)	355(87.0%)		
Hypertension			7.036[a]	0.008
Yes	130(61.3%)	204(50.1%)		
No	82(38.7%)	203(49.9%)		
Diabetes			4.844[a]	0.028
Yes	72(34.0%)	104(25.6%)		
No	140(66.0%)	303(74.4%)		
Craniocerebral disease			4.962[a]	0.026
Yes	37(17.5%)	45(11.1%)		
No	175(82.5%)	362(88.9%)		
Cardiac disease			8.326[a]	0.004
Yes	46(21.7%)	355(87.2%)		
No	166(78.3%)	52(12.8%)		
Malignancy			30.873[a]	<0.001
Yes	35(16.5%)	15(3.7%)		
No	177(83.5%)	392(96.3%)		
Osteoporosis			3.382[a]	0.066
Yes	53(25.0%)	76(18.7%)		
No	159(75.0%)	331(81.3%)		
Surgical procedure			4.838[a]	0.028
THA	174(82.1%)	361(88.5%)		
HA	38(17.9%)	47(11.5%)		
RBC(*10^{12}/L)	3.73±0.69	3.77±0.68	0.722[b]	0.47
PLT(*10^9/L)	206.46±80.03	212.57±83.54	0.876[b]	0.381
HB(g/L)	113.66±18.85	118.76±20.05	3.070[b]	0.002
ALB(g/L)	38.60(37.30,39.60)	41.00(38.70,43.90)	−9.572[b]	<0.001
ALT(U/L)	17(13,25)	18(13,29)	−2.007[c]	0.045
AST(U/L)	23(18,28)	23(18,29)	−0.120[c]	0.904
CRP(mg/L)	22.73(6.6,64.20)	15.95(4.83,37.27)	−2.757[c]	0.006
DBil(μmol/L)	3.25(2.2,4.58)	3.3(2.4,4.3)	−0.372[c]	0.710
IBil(μmol/L)	10.25(7.23,15.38)	9.8(6.6,14.05)	−1.631[c]	0.103
D-dimer(mg/L)	3.51(1.17,8.61)	2.21(0.69,4.81)	−3.982[c]	<0.001
PT(s)	12.01±1.29	11.67±1.38	−3.028[b]	0.003
APTT(s)	30.52±6.27	29.15±4.98	−2.764[c]	0.006
INR	1.02±0.11	0.99±0.95	−3.398[c]	0.001
Type of anaesthesia			1.851[a]	0.174
General anesthesia	180(84.9%)	362(88.7%)		
Spinal anesthesia	32(15.1%)	46(11.3%)		

(*Continued*)

Table 1 (Continued).

Independent Variable	Adverse Outcomes group (n=212)	No Adverse Outcomes Group (n=408)	Statistic value	*P*
ASA grade			81.901[a]	<0.001
III~IV	72(34.0%)	25(6.1%)		
I~II	140(66.0%)	383(93.9%)		
Operation duration(min)	110(90,138.75)	80(65,95)	−11.659[b]	<0.001
Intraoperative	185(140,230)	165(126.25,200)	−3.225[c]	0.001
blood loss(mL)				
Intraoperative blood transfusion			4.373[a]	0.037
Yes	41(19.3%)	53(13.0%)		
No	171(80.7%)	355(87.0%)		
Changeover			12.957[a]	<0.001
Surgery status				
Yes	194(91.5%)	328(80.4%)		
No	18(8.5%)	80(19.6%)		
Postoperative	3(2,5)	3(3,4.75)	−0.043[c]	0.966
pain scores				
Use of drains			1.877[a]	0.171
Yes	100(47.2%)	169(41.4%)		
No	112(52.8%)	239(58.6%)		

Notes: *a, χ2*; b, *t*; c, *Z*.
Abbreviations: BMI, Body mass index; THA, Total hip arthroplasty; HA, Hemiarthroplasty; RBC, Red blood cell; PLT, Platelet; HB, Hemoglobin; ALB, Albumin; ALT, Glutamate aminotransferase; AST, Glutamate oxaloacetate transaminase; CRP, C-reactive protein; DBil, Direct bilirubin; IBil, Indirect bilirubin; PT, Prothrombin time; APTT, Activated partial thromboplastin time; INR, International normalized ratio.

Table 2 Multivariate Regression Results of Postoperative Adverse Outcomes (n = 620)

Independent	β value	Standard error	Wald	*P*	OR	95% CI
Age	0.056	0.016	12.160	<0.001	1.058	1.025~1.092
Malignancy history	1.200	0.485	6.110	0.013	3.319	1.282~8.592
Surgical procedure	−0.749	0.364	4.234	0.040	0.473	0.231~.965
ALB	−0.350	0.045	60.514	<0.001	0.704	0.645~.769
PT	0.169	0.086	3.876	0.049	1.184	1.001~1.400
ASA grade	2.036	0.347	34.412	<0.001	7.657	3.879~15.115
Operation duration	0.041	0.005	73.480	<0.001	1.042	1.032~1.052
Changeover surgery status	0.927	0.368	6.349	0.012	2.527	1.229~5.196
Constant	0.692	2.412	0.082	0.774	1.999	–

Prediction Effect of Adverse Outcomes Prediction Model After Internal Verification of Hip Arthroplasty

The Hosmer-Lemeshow test was conducted for the predictive model, showing $p = 0.712$ and $\chi 2 = 5.418$. ROC curve was used to test the sensitivity and specificity of the patient model in predicting actual adverse outcomes. The maximum Jordon index was the best critical value for the predictive model. The AUC for the modelling group was 0.902 (refer to Figure 3). The Youden index is 0.668, with a sensitivity of 0.84 and a specificity of 0.828 (refer to Table 3).

External Validation of Adverse Outcomes Prediction Model After Hip Arthroplasty

External validation of the model was performed on 264 patients. Postoperative adverse outcomes are observed in 85 cases, corresponding to an incidence rate of 32.20%. The model predicts 93 cases, accurately identifying 67, achieving

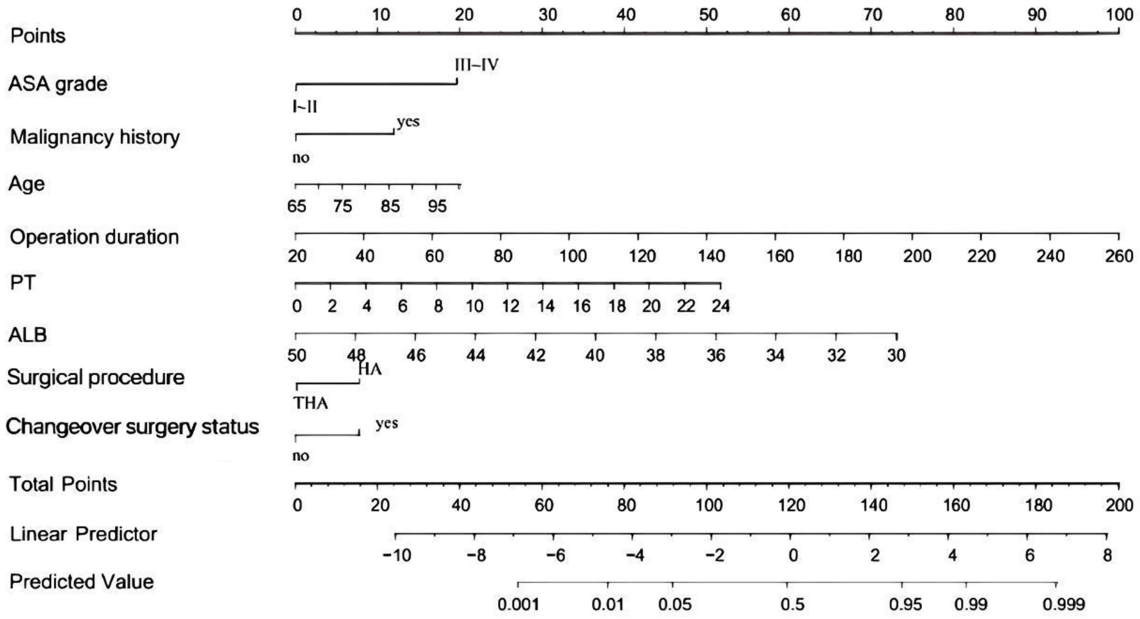

Figure 2 Predictive nomogram for adverse outcomes after Hip arthroplasty in elderly patients.

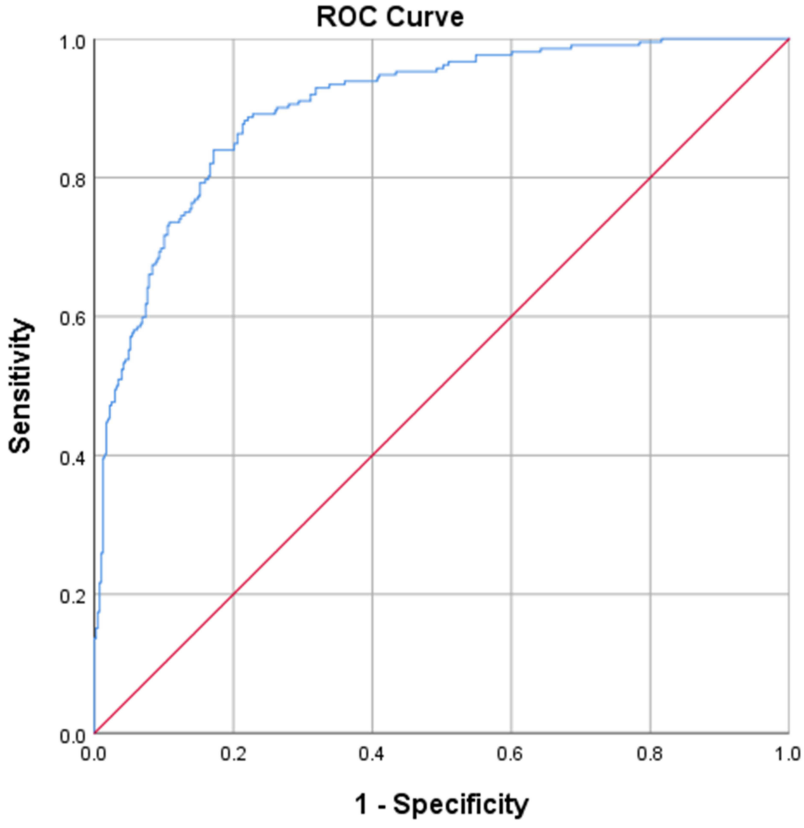

Figure 3 Receiver operating characteristic curve of the modeling group for predicting the risk of adverse outcomes after Hip arthroplasty in elderly patients.

https://doi.org/10.2147/TCRM.S523040

Table 3 Internal Validation Data (n = 620)

Indicator	Numerical value
AUC	0.902
Youden index	0.668
Sensitivity	0.840
Specificity	0.828
NPV	0.909
PPV	0.718

Table 4 Clinical Validation Data (n = 264)

	Adverse Outcomes	No Adverse Outcomes
Predicted values	93	171
Actual value	85	179
Correct value	67	153
Error value	26	18
Specificity	85.47%	
Sensitivity	78.82%	
Accuracy	83.33%	

a sensitivity of 78.82%. Out of 179 cases without adverse outcomes, the model predicts 171, with 153 correct predictions, resulting in a specificity of 85.47%. The total accuracy of the model was (67 + 153)/ 264 = 83.33%, as shown in Table 4.

Discussions

In this study, data from 884 hip arthroplasty patients are analyzed. Risk factors for adverse outcomes are identified through univariate and multivariate logistic regression analyses. The model's validity is confirmed through clinical validation, where the Hosmer-Lemeshow test indicates p = 0.712, the ROC curve area is 0.902, and the prediction accuracy reaches 83.33%. These results demonstrate the model's stability, predictive capability, and clinical utility. Therefore, the model can be used to predict the high-risk group for adverse outcomes after hip arthroplasty and provide a reference for the use of preventive measures.

Serum biomarkers are of great significance for predicting and diagnosing complications after hip arthroplasty. The findings of Moldovan's study demonstrate that the systemic inflammation index (SII) and the neutrophil lymphocyte ratio (NLR) are the most accurate biomarkers for diagnosing periprosthetic joint infection (PJI) following THA.[39] The research by Watanabe et al demonstrated that high serum homocysteine has a significant impact on the incidence of intraoperative periprosthetic fracture.[40] Lin et al's study demonstrates that serum levels of total cholesterol (TG), triglyceride (TC), and low-density lipoprotein (LDL-C) are risk factors for postoperative delirium (POD) after hip arthroplasty, whereas high-density lipoprotein (HDL-C) concentration acts as a protective factor.[41]

This study identifies ASA grade as a significant risk factor for adverse outcomes post-hip arthroplasty, corroborating the findings of Kılınç and Pazarcı.[42] ASA grade is a key indicator of a patient's general health and surgical tolerance, where higher grades often reflect more comorbidities or reduced physiological reserves, thereby heightening the risk of adverse outcomes.[43] Additionally, higher ASA grades correlate with increased anaesthetic and surgical risks during the perioperative period, further raising the probability of complications.[44] Consequently, enhanced perioperative management is crucial for patients with elevated ASA classifications. This includes comprehensive preoperative optimization,

tailored anaesthesia and surgical plans, and rigorous postoperative monitoring and early intervention to reduce risks and enhance patient outcomes.[45]

The results of this study showed that a history of malignancy was a risk factor for adverse outcomes after hip arthroplasty, which is similar to the findings of Karam et al.[46] The study concluded that patients with malignant tumours are usually accompanied by immunocompromised, malnourished, and abnormal coagulation and may have a weakened ability to recover from the organism due to having received radiotherapy, chemotherapy, or other anti-tumour treatments. These factors may increase the risk of postoperative infection, deep vein thrombosis, and other complications.[47] In addition, the postoperative recovery process of patients with malignant tumours may be potentially affected by tumour recurrence or metastasis, further exacerbating the likelihood of adverse outcomes.[48] Therefore, in clinical practice, patients with a history of malignancy should be more comprehensively assessed and prepared during the perioperative period, including optimisation of preoperative nutritional support, strengthening of postoperative anticoagulation and infection prevention and control measures, and development of an individualised follow-up and recovery plan, in order to minimise the risk of adverse outcomes and to improve the patient's postoperative quality of life.[49]

Our data suggest that albumin is a protective factor, which aligns with the findings of Kishawi et al.[50] This may be attributed to the fact that albumin levels reflect the nutritional status and immune function of the patient, with higher albumin levels contributing to improved disease resistance and tissue repair.[51] Preoperative albumin has a strong potential as a valuable indicator for assessing patients' overall health.[52] Therefore, optimizing patients' nutritional status preoperatively, such as by increasing albumin levels through nutritional support, maybe a key intervention to reduce the risk of adverse outcomes in clinical practice.

The results of this study indicate that age, prothrombin time (PT), and operation duration were all risk factors for adverse outcomes after hip arthroplasty. Elderly patients are at a significantly increased risk of postoperative complications due to the presence of more comorbidities, reduced physical function and decreased tissue repair capacity.[19] Prolonged PT may reflect abnormal coagulation or underlying hepatic impairment, which may increase the probability of postoperative complications such as bleeding, haematomas and infections.[53] Prolonged surgical time is usually associated with increased surgical complexity and prolonged exposure time, which may lead to an increased risk of infection and increased physiological stress on the patient.[54] In addition, this study identifies whether the surgery is a changeover procedure as an independent risk factor for adverse outcomes after hip arthroplasty. However, this finding has not been adequately reported in previous studies. Therefore, this study highlights the potential significance of changeover procedures in postoperative risk assessment. Changeover procedures may increase the risk of postoperative infections, tissue damage, and other complications due to factors such as the complexity of operating room resource allocation, increased fatigue of the surgical team, and extended sterile operating time.[55] Further research into the mechanisms linking changeover procedures to postoperative adverse outcomes will not only help optimize surgical scheduling and resource utilization but also provide new perspectives for clinical perioperative management.[56] In addition, this study found that choosing total hip arthroplasty (THA) reduced the risk of postoperative adverse outcomes compared with hemiarthroplasty (HA). However, other studies have shown no significant differences in postoperative complication rates between THA and HA patients.[57,58] This may be attributed to the heterogeneity of the study populations, including variations in patients' underlying health conditions, surgical indications, and the experience of the surgical teams. Therefore, more high-quality studies are needed in the future to investigate further the long-term effects of different surgical modalities on adverse outcomes after hip arthroplasty in order to provide a more reliable and evidence-based basis for the choice of surgical modalities.

Compared to similar studies, this study has several strengths, although it also has some limitations. As the data were collected retrospectively, there may be information bias and potential confounders. Furthermore, while the modelling data were obtained from a single centre, the external validation of the model used an independent dataset from another hospital, partially assessing the model's applicability in a cross-centre setting. Although the validation process enhances the model's reliability, its generalizability to other healthcare settings requires further validation through additional studies, as the modelling data remain limited to a single centre.Additionally, since this study focused solely on adverse outcomes during hospitalization and did not include follow-up, it was not possible to assess the risks associated with long-term prognosis after patient discharge. Future studies could incorporate postoperative follow-up data to provide a more comprehensive assessment of the risk of adverse outcomes after hip arthroplasty, thereby further enhancing the clinical value and applicability of the mode.

Conclusions

In conclusion, this study found that independent risk factors for adverse outcomes after hip arthroplasty included age, malignancy history, PT, ASA grade, operation duration and changeover surgery status, whereas surgical procedure and ALB were protective factors. The nomogram for predicting the risk of adverse outcomes has good consistency and differentiation in predicting the risk and thus can help clinical practitioners assess adverse outcomes after hip arthroplasty with good clinical application.

Data Sharing Statement

The data provided in this study are available upon request from the corresponding author. These data are not publicly available due to privacy restrictions.

Ethics Approval and Consent to Participate

This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of Zhejiang Chinese Medical University, and the requirement for obtaining informed consent was exempted due to retrospective with minimal risk nature of the study. Ethic Reference Number: 20241025-4.

Statement Covering Patient Data Confidentiality

In order to protect patients' personal information and maintain the security of Zhejiang Chinese Medical University Affiliated Hospital's patient information, we are committed to fulfilling our obligation to keep patients' personal information confidential.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used GPT- 4.0 in order to refine the language and enhance the clarity of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Acknowledgments

The authors thank all the participants and instructors who participated in the Study.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

The authors received no specific funding for this work.

Disclosure

All of the authors had no any personal, financial, commercial, or academic conflicts of interest separately.

References

1. Rajpura A, Asle SG, Ait SST, et al. The accuracy of restoration of femoral head centre of rotation in the anteroposterior plane after uncemented total hip arthroplasty: a CT-based study. *Bone Joint Res*. 2022;11(3):180–188. doi:10.1302/2046-3758.113.BJR-2021-0378.R2
2. Hernigou P, Bumbasirevic M, Pecina M, et al. Eight billion people, sixteen billion hip joints today: are future orthopedists prepared to treat a world of ultra-old patients and centenarians in 2050? *Int Orthop*. 2024;48(8):1939–1944. doi:10.1007/s00264-024-06245-x

3. Tan XJ, Gu XX, Ge FM, et al. Nomogram to predict postoperative complications in elderly with total hip replacement. *World J Clin Cases*. 2022;10(12):3720–3728. doi:10.12998/wjcc.v10.i12.3720
4. Boyle KK, Kapadia M, Landy DC, et al. Utilization of debridement, antibiotics, and implant retention for infection after total joint arthroplasty over a decade in the United States. *J Arthroplasty*. 2020;35(8):2210–2216. doi:10.1016/j.arth.2020.03.029
5. Berstock JR, Beswick AD, Lenguerrand E, et al. Mortality after total hip replacement surgery: a systematic review. *Bone Joint Res*. 2014;3(6):175–182. doi:10.1302/2046-3758.36.2000239
6. Yang CC, Bamodu OA, Chan L, et al. Risk factor identification and prediction models for prolonged length of stay in hospital after acute ischemic stroke using artificial neural networks. *Front Neurol*. 2023;14:1085178. doi:10.3389/fneur.2023.1085178
7. Francony F, Montbarbon E, Pailhé R, et al. Assessment of morbidity and mortality after periprosthetic Hip fracture. Influence of Vancouver stage in a retrospective single-centre study of 88 patients. *Orthop Traumatol Surg Res*. 2022;108(1):102985. doi:10.1016/j.otsr.2021.102985
8. Alimy AR, Soltys PJ, Hubert J, et al. Risk factors and prevention strategies for periprosthetic femoral fractures in hip arthroplasty. *Orthopadie*. 2024;53(12):966–973. doi:10.1007/s00132-024-04566-8
9. Tyrpenou E, Megaloikonomos PD, Epure L, et al. Similar complication and readmission rates following simultaneous versus staged bilateral total hip arthroplasty. *Eur J Orthop Surg Traumatol*. 2024;34(2):863–867. doi:10.1007/s00590-023-03734-4
10. Podmore B, Hutchings A, van der Meulen J, et al. Impact of comorbid conditions on outcomes of hip and knee replacement surgery: a systematic review and meta-analysis. *BMJ Open*. 2018;8(7):e021784. doi:10.1136/bmjopen-2018-021784
11. Harris A, Kuo AC, Weng Y, et al. Can machine learning methods produce accurate and easy-to-use prediction models of 30-day complications and mortality after knee or hip arthroplasty? *Clin Orthop Relat Res*. 2019;477(2):452–460. doi:10.1097/CORR.0000000000000601
12. Sweerts L, Hoogeboom TJ, van Wessel T, et al. Development of prediction models for complications after primary total Hip and knee arthroplasty: a single-centre retrospective cohort study in the Netherlands. *BMJ Open*. 2022;12(8):e062065. doi:10.1136/bmjopen-2022-062065
13. Tanaka S, Kayamoto A, Terai C, et al. Preoperative sarcopenia severity and clinical outcomes after total hip arthroplasty. *Nutrients*. 2024;16(13):2085. doi:10.3390/nu16132085
14. Everhart JS, Andridge RR, Scharschmidt TJ, et al. Development and validation of a preoperative surgical site infection risk score for primary or revision knee and hip arthroplasty. *J Bone Joint Surg Am*. 2016;98(18):1522–1532. doi:10.2106/JBJS.15.00988
15. Inacio MC, Pratt NL, Roughead EE, et al. Predicting infections after total joint arthroplasty using a prescription based comorbidity measure. *J Arthroplasty*. 2015;30(10):1692–1698. doi:10.1016/j.arth.2015.05.004
16. Klemt C, Tirumala V, Smith EJ, et al. Development of a preoperative risk calculator for reinfection following revision surgery for periprosthetic joint infection. *J Arthroplasty*. 2021;36(2):693–699. doi:10.1016/j.arth.2020.08.004
17. Tan TL, Maltenfort MG, Chen AF, et al. Development and evaluation of a preoperative risk calculator for periprosthetic joint infection following total joint arthroplasty. *J Bone Joint Surg Am*. 2018;100(9):777–785. doi:10.2106/JBJS.16.01435
18. Zotov E, Hills AF, de Mello FL, et al. JointCalc: a web-based personalised patient decision support tool for joint replacement. *Int J Med Inform*. 2020;142:104217. doi:10.1016/j.ijmedinf.2020.104217
19. Li L, Lu Y, Yang LL, et al. Construction and validation of postoperative hypothermia prediction model for patients undergoing joint replacement surgery. *J Clin Nurs*. 2023;32(13–14):3831–3839. doi:10.1111/jocn.16503
20. Edelstein AI, Kwasny MJ, Suleiman LI, et al. Can the American college of surgeons risk calculator predict 30-day complications after knee and hip arthroplasty? *J Arthroplasty*. 2015;30(9 Suppl):5–10. doi:10.1016/j.arth.2015.01.057
21. Steyerberg EW, Moons KG, van der Windt DA, et al. Prognosis research strategy (PROGRESS) 3: prognostic model research. *PLoS Med*. 2013;10(2):e1001381. doi:10.1371/journal.pmed.1001381
22. Mula V, Parikh S, Suresh S, et al. Venous thromboembolism rates after hip and knee arthroplasty and hip fractures. *BMC Musculoskelet Disord*. 2020;21(1):95. doi:10.1186/s12891-020-3100-4
23. Nemeth B, Smeets M, Pedersen AB, et al. Development and validation of a clinical prediction model for 90-day venous thromboembolism risk following total hip and total knee arthroplasty: a multinational study. *J Thromb Haemost*. 2024;22(1):238–248. doi:10.1016/j.jtha.2023.09.033
24. Iliopoulou-Kosmadaki S, Hadjimichael AC, Kaspiris A, et al. Impact of preoperative quality of life and related factors on the development of surgical site infections following primary total joint arthroplasty: a prospective case-control study with a five-year follow-up. *Adv Orthop*. 2023;2023:7010219. doi:10.1155/2023/7010219
25. Sigurdardottir M, Sigurdsson MI, Vias RD, et al. Preoperative optimization of modifiable risk factors is associated with decreased superficial surgical site infections after total joint arthroplasty: a prospective case-control study. *Acta Orthop*. 2024;95:392–400. doi:10.2340/17453674.2024.41012
26. Kostewicz M, Szczęsny G, Tomaszewski W, et al. Narrative review of the mechanism of hip prosthesis dislocation and methods to reduce the risk of dislocation. *Med Sci Monit*. 2022;28:e935665. doi:10.12659/MSM.935665
27. Gillinov SM, Joo PY, Zhu JR, et al. Incidence, timing, and predictors of hip dislocation after primary total hip arthroplasty for osteoarthritis. *J Am Acad Orthop Surg*. 2022;30(21):1047–1053. doi:10.5435/JAAOS-D-22-00150
28. Kumar P, Ksheersagar V, Aggarwal S, et al. Complications and mid to long term outcomes for Hip resurfacing versus total hip replacement: a systematic review and meta-analysis. *Eur J Orthop Surg Traumatol*. 2023;33(5):1495–1504. doi:10.1007/s00590-022-03361-5
29. Wang L, Xu Z, Zhang L. A comparison between fondaparinux sodium and low-molecular-weight heparin in preventing patients undergoing hip replacement from deep vein thrombosis. *J Musculoskelet Neuronal Interact*. 2024;24(2):185–191.
30. Tan H, Wu J, Zhang R, et al. Development, validation, and application of a human reproductive toxicity prediction model based on adverse outcome pathway. *Environ Sci Technol*. 2022;56(17):12391–12403. doi:10.1021/acs.est.2c02242
31. Riley RD, Ensor J, Snell K, et al. Calculating the sample size required for developing a clinical prediction model. *BMJ*. 2020;368:m441. doi:10.1136/bmj.m441
32. Collins GS, Ogundimu EO, Altman DG. Sample size considerations for the external validation of a multivariable prognostic model: a resampling study. *Stat Med*. 2016;35(2):214–226. doi:10.1002/sim.6787
33. Zhou X, Tan P, Huo M, et al. Development and verification of a prediction model for outcomes of elderly patients with nursing home-acquired pneumonia. *Appl Nurs Res*. 2024;78:151816. doi:10.1016/j.apnr.2024.151816
34. Hong H, Zhang L, Hong F, et al. Prediction of adverse maternal and perinatal outcomes in preeclampsia based on B-type natriuretic peptide: a retrospective study. *Ann Palliative Med*. 2021;10(12):12190–12207. doi:10.21037/apm-21-2981

35. Bertsimas D, Zhuo D, Dunn J, et al. Adverse outcomes prediction for congenital heart surgery: a machine learning approach. world. *J Pediatr Congenit Heart Surg*. 2021;12(4):453–460. doi:10.1177/21501351211007106
36. Liu H, Xing F, Jiang J, et al. Random forest predictive modeling of prolonged hospital length of stay in elderly hip fracture patients. *Front Med Lausanne*. 2024;11:1362153. doi:10.3389/fmed.2024.1362153
37. Wilson R, Margelyte R, Redaniel MT, et al. Risk factors for prolonged length of hospital stay following elective Hip replacement surgery: a retrospective longitudinal observational study. *BMJ Open*. 2024;14(8):e078108. doi:10.1136/bmjopen-2023-078108
38. Sun J, Huang L, Yang Y, et al. Risk assessment and clinical prediction model of planned transfer to the ICU after Hip arthroplasty in elderly individuals. *BMC Surg*. 2023;23(1):305. doi:10.1186/s12893-023-02204-2
39. Moldovan F. Role of serum biomarkers in differentiating periprosthetic joint infections from aseptic failures after total hip arthroplasties. *J Clin Med*. 2024;13(19):5716. doi:10.3390/jcm13195716
40. Watanabe N, Ogawa T, Takada R, et al. Association of osteoporosis and high serum homocysteine levels with intraoperative periprosthetic fracture during total hip arthroplasty: a propensity-score matching analysis. *Arch Orthop Trauma Surg*. 2023;143(12):7219–7227. doi:10.1007/s00402-023-04989-6
41. Lin Y, Peng X, Lin X, et al. Potential value of serum lipid in the identication of postoperative delirium undergoing knee/hip arthroplasty: the perioperative neurocognitive disorder and biomarker lifestyle study. front. *Psychiatry*. 2022;13:870317. doi:10.3389/fpsyt.2022.870317
42. Kılınç S, Pazarcı Ö. Investigating the risk factors that affect mortality after cemented hemiarthroplasty in advanced age patients. *J Orthop*. 2020;21:249–252. doi:10.1016/j.jor.2020.03.031
43. Quach LH, Jayamaha S, Whitehouse SL, et al. Comparison of the Charlson Comorbidity Index with the ASA score for predicting 12-month mortality in acute Hip fracture. *Injury*. 2020;51(4):1004–1010. doi:10.1016/j.injury.2020.02.074
44. Haugan K, Klaksvik J, Foss OA. 30-day mortality in patients after hip fracture surgery: a comparison of the Charlson Comorbidity Index score and ASA score used in two prediction models. *Injury*. 2021;52(8):2379–2383. doi:10.1016/j.injury.2021.02.004
45. Cher E, Carson JA, Sim EY, et al. Developing a simpler prognosticating tool: comparing the combined assessment of risk encountered in surgery score with Deyo-Charlson comorbidity index and the American Society of Anesthesiologists physical status score in predicting 2 years mortality after hip fracture surgery. *Geriatr Orthop Surg Rehabil*. 2021;12:21514593211036235. doi:10.1177/21514593211036235
46. Karam JA, Huang RC, Abraham JA, et al. Total joint arthroplasty in cancer patients. *J Arthroplasty*. 2015;30(5):758–761. doi:10.1016/j.arth.2014.12.017
47. Duan X, Liu M, Wang P. Effects of the concept of fast-track surgery combined with empathic nursing on perioperative complication prevention and postoperative recovery of gynecological malignant tumor patients. *Comput Math Methods Med*. 2022;2022:4381297. doi:10.1155/2022/4381297
48. Yang R, Wu Y, Qi Y, et al. A nomogram for predicting breast cancer specific survival in elderly patients with breast cancer: a SEER population-based analysis. *BMC Geriatr*. 2023;23(1):594. doi:10.1186/s12877-023-04280-8
49. Zhang Q, Zhang M, Hu S, et al. Prevalence and risk factors of preoperative frailty in Chinese elderly inpatients with gastric and colorectal cancer undergoing surgery: a single-center cross-sectional study using the Groningen frailty indicator. *Support Care Cancer*. 2022;30(1):677–686. doi:10.1007/s00520-021-06483-4
50. Kishawi D, Schwarzman G, Mejia A, et al. Low preoperative albumin levels predict adverse outcomes after total joint arthroplasty. *J Bone Joint Surg Am*. 2020;102(10):889–895. doi:10.2106/JBJS.19.00511
51. Labgaa I, Mantziari S, Genety M, et al. Early postoperative decrease of albumin is an independent predictor of major complications after oncological esophagectomy: a multicenter study. *J Surg Oncol*. 2021;123(2):462–469. doi:10.1002/jso.26317
52. Gupta A, Upadhyaya S, Cha T, et al. Serum albumin levels predict which patients are at increased risk for complications following surgical management of acute osteoporotic vertebral compression fractures. *Spine J*. 2019;19(11):1796–1802. doi:10.1016/j.spinee.2019.06.023
53. Ding R, Ding Y, Zheng D, et al. Machine learning-based screening of risk factors and prediction of deep vein thrombosis and pulmonary embolism after hip arthroplasty. *Clin Appl Thromb Hemost*. 2023;29:10760296231186145. doi:10.1177/10760296231186145
54. Thakker PU, Hemal AK, Geldmaker L, et al. Creation of a novel, race-adjusted, and risk-adapted scoring system to predict positive surgical margins and prolonged operative time during robotic radical prostatectomy. *J Endourol*. 2024;38(1):40–46. doi:10.1089/end.2023.0210
55. Gates M, Wingert A, Featherstone R, et al. Impact of fatigue and insufficient sleep on physician and patient outcomes: a systematic review. *BMJ Open*. 2018;8(9):e021967. doi:10.1136/bmjopen-2018-021967
56. Sun EC, Mello MM, Vaughn MT, et al. Assessment of perioperative outcomes among surgeons who operated the night before. *JAMA Intern Med*. 2022;182(7):720–728. doi:10.1001/jamainternmed.2022.1563
57. Liu Y, Chen X, Zhang P, et al. Comparing total hip arthroplasty and hemiarthroplasty for the treatment of displaced femoral neck fracture in the active elderly over 75 years old: a systematic review and meta-analysis of randomized control trials. *J Orthop Surg Res*. 2020;15(1):215. doi:10.1186/s13018-020-01725-3
58. Luo S, Qin W, Yu L, et al. Total Hip arthroplasty versus hemiarthroplasty in the treatment of active elderly patients over 75 years with displaced femoral neck fractures: a retrospective study. *BMC Musculoskelet Disord*. 2023;24(1):745. doi:10.1186/s12891-023-06860-6