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Research Article

Development of a Predictive Model for Hip Dislocation Following Total Hip Arthroplasty in Patients with Spinal Disorders

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Abstract

Introduction: Total hip arthroplasty (THA) is an effective treatment for advanced hip conditions, yet postoperative dislocation remains a significant complication, especially in patients with spinal disorders. Altered spinopelvic alignment and reduced spinal mobility can lead to prosthetic instability. Given the growing prevalence of coexisting conditions, this study aimed to develop a predictive model to identify individuals at increased risk of hip dislocation after THA with spinal abnormalities.

Method: This descriptive cross-sectional study was conducted over 10 years, until 2023, at Shohada Hospital, including 225 patients (75 with spinal disorders and 150 controls) who experienced hip dislocation after total hip arthroplasty. Key variables, including demographic data, surgical factors, comorbidities, and medication history, were analyzed.

Result: In this study, two predictive models were developed to assess the postoperative risk of hip dislocation in patients with spinal disorders. Model I, based on logistic regression, included 14 variables and showed moderate discrimination (C-index=0.67) but limited calibration and low R^2 (0.04). Model II, using elastic net regression, selected nine key predictors—including hip rotation, anemia, BMI 30–35, and certain medications—and achieved better discrimination (AUC=0.73), though with similarly low explanatory power (R^2=0.02).

Conclusion : This study identified demographic variables (age, BMI), clinical factors (history of psychosis, preoperative anemia), surgical parameters (type of femoral fixation, preoperative hip internal rotation, surgical indication), and medication use (antiepileptic drugs, muscle relaxants, antidiabetic medications) as significant predictors of postoperative hip dislocation risk following total hip arthroplasty in patients with spinal disorders.

Keywords: Total Hip Replacement, Hip Dislocation, Spinal Disorders, Predictive Model, prosthetic instability.

Introduction

THA is widely regarded as one of the most effective surgical interventions for the treatment of advanced hip joint diseases such as osteoarthritis, avascular necrosis of the femoral head, and complex hip fractures.[1] Despite significant advancements in prosthetic design, surgical techniques, and perioperative care protocols, postoperative complications remain a concern. [2] Among these, hip dislocation stands out as a relatively common and serious complication, often resulting in functional impairment, diminished quality of life, and increased healthcare costs.[3]

The incidence of dislocation following THA has been reported to range from 0.2% to 10%, depending on patient characteristics and surgical factors. [4] Recent studies have identified specific subgroups—particularly patients with spinal disorders—as being at higher risk. [5] Spinal conditions such as lumbar spinal fusion, degenerative scoliosis, and abnormalities in spinopelvic alignment have been increasingly recognized as critical contributors to prosthetic instability after THA. [6]

The concept of spinopelvic mobility—the dynamic relationship between spinal alignment, pelvic tilt, and acetabular orientation—has emerged as a key factor in understanding hip biomechanics. [7] In patients with reduced spinal flexibility or lumbopelvic mismatch, alterations in pelvic tilt during position changes (e.g., from standing to sitting) may disrupt the intended functional orientation of the acetabular component. As a result, even well-positioned implants may become functionally malaligned, predisposing the patient to dislocation. [8, 9]

Given the complexity of these biomechanical interactions, there is growing interest in developing predictive models to identify individuals at increased risk of dislocation before surgery. [10] Such models can aid clinicians in surgical planning, including optimal component positioning, choice of implant design, and consideration of simultaneous or staged spinal procedures in high-risk individuals. [11]

Predictive modeling in medicine—particularly through statistical approaches such as logistic regression and, increasingly, machine learning and AI-based techniques—offers a powerful tool for risk stratification. [12] By integrating demographic data, clinical history, radiographic findings, and biomechanical parameters, these models can provide individualized risk estimates, potentially improving patient outcomes and resource allocation.[13]

Although several models have been proposed to predict dislocation after THA, most have not explicitly focused on patients with spinal pathologies. This represents a critical gap in the literature, as these patients may require different surgical considerations. Furthermore, existing models vary widely in terms of their predictive accuracy, external validity, and clinical utility. The present study was therefore designed to develop and validate a predictive model specifically to estimate the risk of hip dislocation following THA in patients with spinal disorders.

Methods

Study Design

The present study is a descriptive cross-sectional investigation conducted over a ten-year period ending in 2023 at Shahid Hospital affiliated with Tabriz University of Medical Sciences.

Sampling

A census sampling method was employed in this study, including all patients with spinal disorders who underwent total hip arthroplasty and subsequently experienced postoperative hip dislocation, provided they met the inclusion and exclusion criteria. Over the specified timeframe, 75 eligible patients were enrolled. For a comprehensive analysis, a control group consisting of 150 patients who underwent total hip arthroplasty, experienced postoperative hip dislocation, but had no spinal issues, was also included.

Eligibility Criteria

*Patient Group***:** Inclusion criteria comprised patients over 18 years of age who underwent total hip arthroplasty and had a confirmed diagnosis of spinal disorders such as scoliosis, spondylolisthesis, or degenerative disc disease, and subsequently experienced postoperative hip dislocation. All participants provided informed consent to participate in the study. Exclusion criteria included a history of multiple prior surgeries involving the pelvis or spine that could affect study outcomes, active local or systemic infections, and inability to complete follow-up or provide complete data.

Control Group: Inclusion criteria consisted of patients over 18 years' old who underwent total hip arthroplasty and developed postoperative hip dislocation but had no evidence of spinal disease or abnormalities, as confirmed by orthopedic or radiologic evaluation. Participants also provided informed consent. Exclusion criteria included any history of spinal disorders or neuromuscular diseases, presence of infection or severe postoperative complications that could influence results, and lack of access to complete medical records.

In this study, individuals classified as having spinal problems (spine disorders) are those diagnosed with definitive structural or functional abnormalities of the spine, including conditions such as scoliosis, kyphosis, spondylolisthesis, degenerative disc disease, vertebral degeneration, or other chronic and progressive spinal deformities. These disorders may alter the biomechanics and stability of the pelvis and hip joint, potentially impacting the outcomes of total hip arthroplasty and increasing the risk of postoperative complications such as dislocation. The diagnosis of spinal problems was established through a comprehensive clinical evaluation and confirmed by radiological imaging.

In this study, a comprehensive set of variables was systematically recorded for each patient to evaluate factors potentially influencing postoperative outcomes. These variables included demographic data, such as age (categorized into five groups: <45, 45–55, 55–65, 65–75, and >75 years) and gender. Clinical characteristics comprised the site of involvement (right or left), height (cm), weight (kg), and body mass index (BMI). Surgical parameters encompassed duration of surgery (minutes), surgical approach (posterior, anterior, anterolateral), femoral fixation method (cemented or uncemented), and femoral head size (ranging from 22 mm to ≥40 mm). Additionally, patient medical history variables included the presence of psychiatric or neurological diseases, use of anti-Parkinson and antiepileptic medications, and normal serum creatinine levels. Follow-up duration was documented as median years with interquartile range. The primary indications for surgery were classified as primary osteoarthritis, femoral neck fracture, developmental dysplasia of the hip, avascular necrosis of the femoral head, or other reasons. Finally, the American Society of Anesthesiologists (ASA) physical status classification was recorded for all patients, ranging from I to IV. These variables were meticulously collected for each patient to enable a thorough analysis of their potential impact on postoperative hip dislocation.

Data analysis

The collected data were entered and processed using SPSS software version 25. Descriptive statistics were presented as mean ± standard deviation, median with interquartile range, frequency, and percentage as appropriate. Between-group comparisons were performed using the independent t-test, one-way analysis of variance (ANOVA), Chi-square test, and Mann–Whitney U test. A p-value of less than 0.05 was considered statistically significant.

Model I

In this study, an initial predictive model was developed based on logistic regression. Variable selection for the predictor set was guided by criteria identified in prior scientific literature associated with hip dislocation in individuals with spinal disorders or those that potentially influence the risk of dislocation. The primary sources of literature included recent systematic reviews and meta-analyses on risk factors for dislocation. The variables incorporated into the model encompassed patient characteristics such as age, gender, American Society of Anesthesiologists (ASA) score, body mass index (BMI), and the primary indication for surgery (e.g., primary osteoarthritis, hip fracture, avascular necrosis of the femoral head, rheumatoid arthritis, or other etiologies). Additionally, factors related to surgical fixation methods—including the type of femoral and acetabular fixation (cemented or cementless) and femoral head size—were included as surgical or implant-related variables.

To assess potential multicollinearity among the predictor variables, an overfitting analysis based on linear regression was conducted. Model calibration was improved through the application of single imputation techniques. The overall predictive performance of the model was evaluated by calculating the Nagelkerke R^2, which measures the proportion of variance in the outcome explained by the predictor variables. This metric ranges from zero to one, where zero indicates no explanatory power beyond chance, and one signifies perfect prediction capability.

Discrimination of the model was assessed via the concordance index (C-index). A C-index value of 0.5 indicates performance equivalent to random chance, whereas a value of 1.0 signifies perfect discrimination, enabling the model to accurately predict all outcomes within the dataset. For continuous variables such as age and BMI, restricted cubic splines with three knots were employed to accurately model potential nonlinear relationships with the outcome. The relative importance of each predictor in the final model was quantified using Wald chi-square statistics and associated p-values, derived from parent-specified hypotheses testing.

Model II

The second predictive model employed an elastic net regularization approach, a machine learning technique that extends linear regression by incorporating penalty terms into the loss function. This method systematically searches for an optimal combination of predictors by penalizing model complexity, effectively removing weak and highly collinear predictors, thereby enhancing model stability and predictive accuracy. The elastic net has demonstrated utility in predictive modeling contexts related to total joint arthroplasty studies.

The primary objective of this analysis was to maximize the area under the curve (AUC), which, similar to the C-index, reflects the model's discriminative ability. The pseudo R^2 value—comparable to the R^2 from the first model—was calculated for the elastic net model. All variables available in our database that were considered potentially relevant were included in these analyses. In addition to all the predictors used in the first model, the following variables were incorporated into the elastic net analyses: preoperative hip range of motion (extension, flexion, abduction, adduction, internal and external rotation), history of psychosis or previous trauma, diagnosis of osteoporosis, anemia, dementia, diabetes, or hemiplegia, smoking status, use of corticosteroids, muscle relaxants, beta-blockers, antidiabetic drugs, or gastrointestinal medications within the past 365 days, surgical approach, and whether the surgery was bilateral or performed as a training procedure. In this model, age and BMI were analyzed categorically based on predefined cut-off values (0–50, 50–65, 65–75, 75+ for age; and 0–25, 25–30, 30–35, 35–40, 40+ for BMI). The relative importance of each predictor variable in this model was not evaluated.

Results

Comparison of demographic characteristics between the two groups—those with and without spinal problems—revealed that age (P=0.041), follow-up (P=0.042) and body mass index (BMI) (P=0.042) were significantly higher in the group with issues; Femoral fixation was more frequently performed in the group with spinal problems ($p = 0.047$), and larger femoral head sizes were used in patients with spinal issues ($p = 0.039$). There were no statistically significant differences between the groups in variables such as surgical side, height, weight, duration of surgery, gender, or the presence of underlying medical conditions (Table 1).

In the redundancy analysis conducted for the predictive Model based on a logistic regression approach—aimed at identifying factors associated with postoperative hip dislocation in patients with underlying spinal disorders—the R^2 value for each predictor variable represented the proportion of its variance explained by the other variables in the Model. In this study, all examined variables demonstrated R^2 values well below the predefined threshold of 0.8. Accordingly, the value of 0.8 was adopted as the cutoff for identifying and excluding redundant or non-essential variables. Since none of the variables exceeded this threshold, it was decided to retain all of them in the final Model without excluding any (Table 2).

Assessment of Model I is predictive accuracy revealed calibration deficiencies. Specifically, the Model tended to overestimate the risk of dislocation in patients with a low likelihood of dislocation (i.e., those without spine problems). Conversely, in patients at the highest risk (those with spinal conditions), the Model underestimated the actual dislocation probability. The findings of this study indicate that Model I was prone to either overestimating or underestimating the risk in different patient subgroups (those with and without spine disorders) (Figure 1).

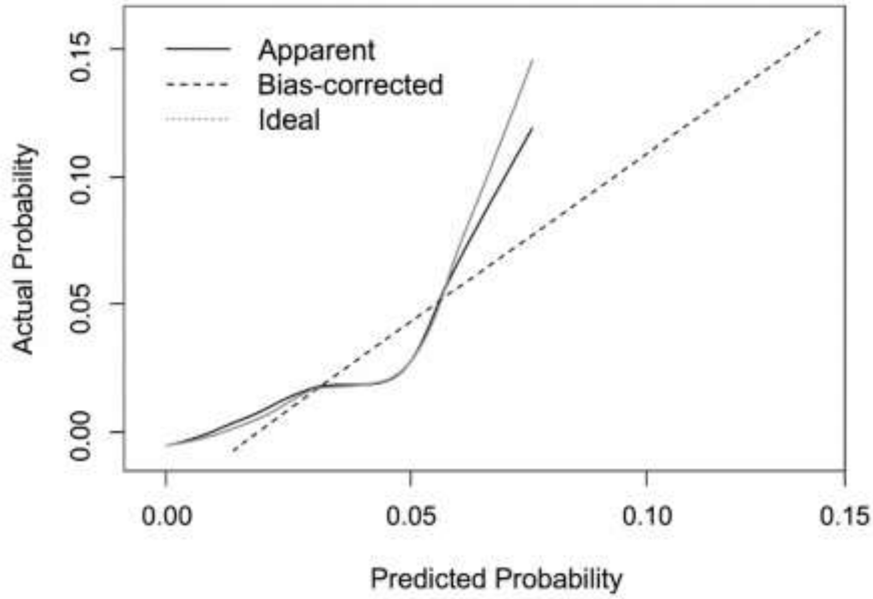

Figure 1. Calibration Plot of Model I for Predicting Dislocation Risk According to Patients' Spine Status

In the first model, based on logistic regression, all 14 final predictor variables—selected by a clinical expert based on the results of redundancy analysis—were included (Table 1).

The model achieved a C-index of 0.67. However, the R^2 value was only 0.04, indicating relatively limited predictive performance. Among the included variables, femoral fixation type, antiepileptic medication use, and the primary indication for surgery emerged as the most influential predictors of early revision due to hip dislocation in patients with underlying spinal disorders (Figure 2).

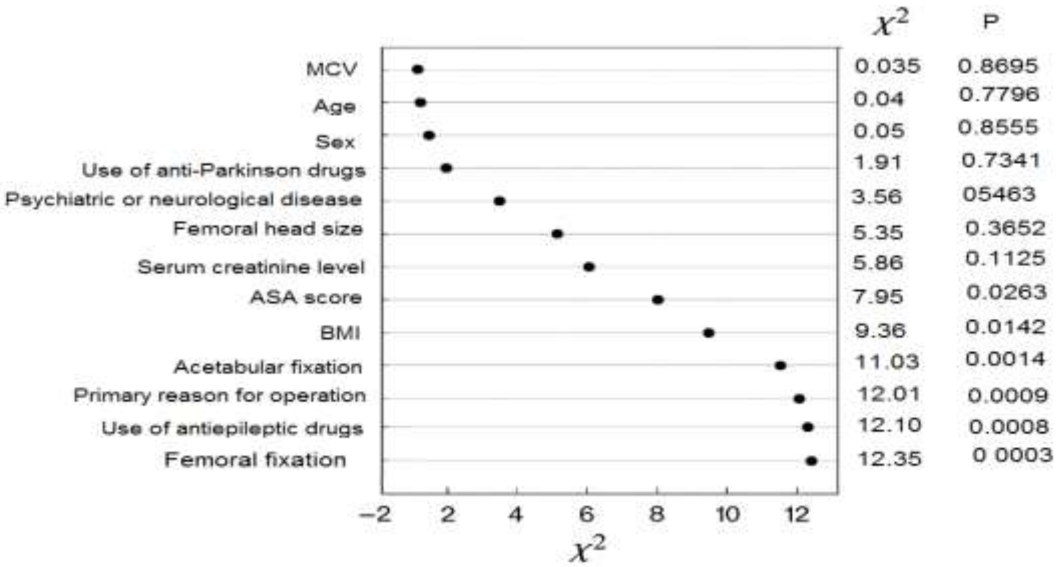

Figure 2. Comparison of predictor importance in the regression model I

Table 1. Comparison of Demographic Information of Study Participants

Variable		Participants in the Study		P Value
		Patients with Spine Issues (75 patients)	Patients without Spine Issues (150 patients)	
Age (years)		68.96 ± 19.5	63.78 ± 5.25	0.041 *
Age (years)	Under 45	0 (0%)	17 (11.33%)	0.048 **
	45-55	12 (16%)	28 (18.67%)	
	55-65	15 (20%)	45(30%)	
	65-75	28 (37.33 %)	40 (26.67%)	
	Over 75	20 (26.67%)	20 (13.33%)	
Site of Involvement	Right	45 (60%)	96 (64%)	0.851 ***
	Left	30 (40%)	54 (37%)	
Height (cm)		155.96 ± 15.03	165.45 ± 15.10	0.551 *
Weight (kg)		92.96 ± 8.96	81.26 ± 10.10	0.075 *
Body Mass Index		29.09 ± 3.96	25.59 ± 3.55	0.042 *
Duration of Surgery (minutes)		199.96 ± 25.63	189.25 ± 18.65	0.773 *
Psychiatric or neurological disease (n, %)		30 (40%)	45(30%)	0.251 ***
Use of anti-Parkinson drugs (n, %)		12 (16%)	17 (11.33%)	0.759 ***
Normal Serum creatinine level (n, %)		61 (81.33 %)	102 (68 %)	0.055 ***
Use of antiepileptic drugs (n, %)		7 (9.33%)	4 (2.67%)	0.066 ***
Gender (Male)		49 (65.33%)	96 (64%)	0.937 ***
Follow-up (Years, median, IQR)		1.4 (0.5–3.2)	4.0 (1.5–7.3)	0.042 &
Primary reason for operation (n, %)	Primary osteoarthritis	29 (38.67%)	55 (36.67%)	0.114 **
	Femoral neck fracture	32 (44.44%)	69 (46%)	
	Developmental dysplasia of the hip	6 (8%)	21 (14%)	
	Avascular necrosis of the femoral head	7 (9.33%)	4 (2.67%)	
	Other reason	1 (1.33%)	1 (0.67%)	
ASA score (n, %)	I	9 (12%)	38 (25.33%)	0.078 **
	II	15 (20%)	30 (20%)	
	III	36 (48%)	49 (32.67%)	
	IV	15 (20%)	33 (22%)	
Approach (n, %)	Posterior	23 (30.67%)	39 (26%)	0.069 **
	Anterior	41 (54.67%)	68 (45.33%)	
	Anterolateral	11 (14.67%)	43 (28.67%)	
Femoral fixation (n, %)	Cemented	26 (34.67%)	81 (54%)	0.047 ***
	Uncemented	49 (65.33%)	69 (46%)	
Femoral head size (n, %)	22 mm	0 (0%)	9 (6%)	0.039 ***
	28 mm	15 (20%)	41 (27.33%)	
	32 mm	18 (24%)	63 (42%)	
	35 mm	22 (29.33%)	21 (14%)	
	36 mm	16 (21.33%)	13 (8.67%)	
	≥ 40 mm	4 (5.33%)	3 (2%)	

***: T-test; **: ANOVA; ***:Chi Square &: Mann Whitney U test**

Table 2. Redundancy Analysis of Predictor Variables for Inclusion in the Logistic Regression Model

Prediction variable	R2 value
Age	0.45
Sex	0.13
ASA score	0.40
BMI	0.15
Primary reason for operation	0.10
Psychiatric or neurological disease	0.06
Serum creatinine level	0.15
Use of anti-Parkinson drugs	0.03
Use of antiepileptic drugs	0.03
Femoral fixation	0.35
Acetabular fixation	0.15
Femoral head size	0.12

In the second model, based on elastic net regression, variable selection was performed automatically, resulting in the inclusion of 9 predictors in the final model. These variables included preoperative internal rotation of the hip, avascular necrosis of the femoral head as the surgical indication, preoperative anemia, type of femoral fixation, body mass index (BMI) in the range of 30–35, history of psychosis, and the use of antiepileptic drugs, muscle relaxants, and antidiabetic medications. This combination of variables yielded an area under the curve (AUC) of 0.73, with a 95% confidence interval ranging from 0.67 to 0.78. However, the R^2 value remained low at 0.02, indicating limited predictive power of the model in identifying risk factors for postoperative hip dislocation following total hip arthroplasty in patients with spinal disorders (Figure 3-4).

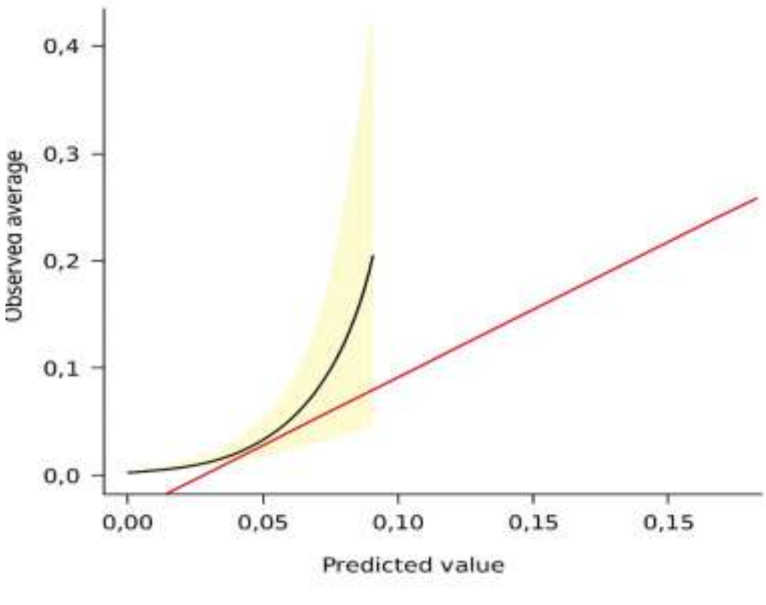

Figure 3. The calibration plot corresponding to the elastic net model (Model II)

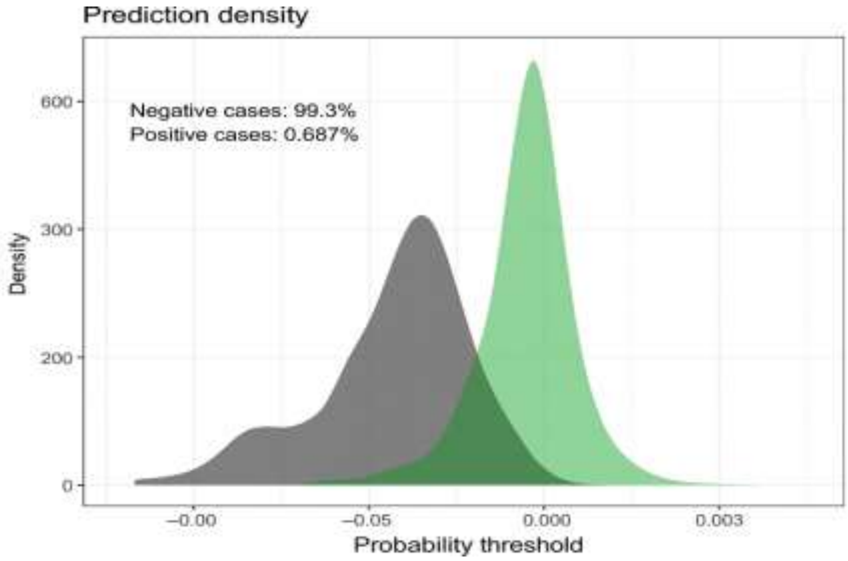

Figure 4. Comparison of predictor importance in the regression model II

Discussion

This study aimed to develop predictive models to assess the risk of hip dislocation following total hip arthroplasty (THA) in patients with spinal disorders. Two statistical approaches were employed: the first based on classical logistic regression with variables selected via redundancy analysis, and the second based on a machine learning technique known as Elastic Net. The redundancy analysis in the logistic regression model revealed that none of the variables had an R^2 value exceeding 0.8, indicating minimal multicollinearity and supporting the inclusion of all candidate predictors. This suggests that each variable may contribute uniquely to predicting hip dislocation in this patient population.

Despite this, Model I exhibited calibration issues. It overestimated dislocation risk in patients without spinal disorders and underestimated it in those with spinal conditions, limiting its clinical applicability. The C-index of 0.67 indicated moderate discrimination, but the low R^2 value of 0.04 reflected limited explanatory power, highlighting the Model's constrained ability to account for the variability in dislocation outcomes.

Among predictors in Model I, femoral fixation type (cemented vs. cementless), use of antiepileptic medications, and the primary surgical indication (e.g., avascular necrosis or primary osteoarthritis) emerged as the most influential factors. [14] The association of antiepileptic drug use with dislocation risk is clinically plausible, as these medications often cause muscle weakness, impaired coordination, and decreased bone density—factors that compromise joint stability. [15] Additionally, patients on these drugs frequently have underlying neurological disorders that may contribute to abnormal gait patterns and reduced muscle strength around the hip. [16] Possible interactions between antiepileptic drugs and anesthesia or postoperative medications could further affect neuromuscular control, increasing dislocation risk. Surgical indication is another critical factor; avascular necrosis often involves significant anatomical distortion and poor bone quality, which reduces intrinsic joint stability and complicates successful arthroplasty. [17] Conversely, patients undergoing THA for primary osteoarthritis generally exhibit more stable bone anatomy, resulting in lower dislocation rates. These findings emphasize the importance of considering both underlying pathology and medication use when assessing dislocation risk. [18]

Model II, developed using Elastic Net regularization, enabled automatic, optimized variable selection to reduce overfitting. Nine predictors were retained: preoperative internal hip rotation, avascular necrosis as the surgical indication, preoperative anemia, femoral fixation type, BMI between 30 and 35, history of psychosis, and use of antiepileptic drugs, muscle relaxants, and antidiabetic medications. Limited preoperative internal rotation likely reflects impaired pelvic and hip muscle function and anatomical alterations, decreasing joint stability after surgery. Avascular necrosis leads to femoral head deformation and bone loss, further destabilizing the joint. Anemia reduces oxygen delivery and muscle strength, hampering rehabilitation and compromising stability. Femoral fixation type is crucial, especially in patients with poor bone quality, as unstable fixation increases the risk of displacement. Elevated BMI imposes greater mechanical load and limits mobility, increasing dislocation susceptibility. Psychosis history may impair postoperative adherence and lead to involuntary movements, exerting abnormal joint stress. Antiepileptic drugs reduce muscle tone and impair balance; uncontrolled seizures can directly cause dislocation. Muscle relaxants diminish the support from periarticular muscles, and antidiabetic medications are associated with neuropathy and muscle weakness, both of which decrease joint stability. [19-23]

Compared with Model II, which demonstrated improved discriminative ability (AUC of 0.73), both models had limited capacity to explain risk factors for hip dislocation in this cohort fully. Contributing factors to this limitation may include a relatively small sample size—especially among patients with spinal disorders—clinical heterogeneity, and unmeasured variables. Important aspects such as radiographic joint characteristics, surgical technique, surgeon expertise, pelvic muscle function, and quality of postoperative rehabilitation were not incorporated, though they likely significantly influence dislocation risk.

Conclusion

This study identified demographic variables (age, BMI), clinical factors (history of psychosis, preoperative anemia), surgical parameters (type of femoral fixation, preoperative hip internal rotation, surgical indication), and medication use (antiepileptic drugs, muscle relaxants, antidiabetic medications) as significant predictors of postoperative hip dislocation risk following total hip arthroplasty in patients with spinal disorders.

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Conflict of Interest Disclosures

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Authors' Contributions

Mehrdad Zamani: Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft.
Aran Nikpay: Methodology, Software, Validation, Visualization, Writing – review & editing.
Mohamadreza Hashemi Aghdam: Investigation, Resources, Data curation, Project administration.
Ali Dezhpasand: Methodology, Formal analysis, Software, Writing – review & editing.
Alireza Sadeghpour: Conceptualization, Supervision, Funding acquisition (if any), Writing – review & editing, Final approval.

Ethical Statement

This study was approved by the Ethics Committee of Tabriz University of Medical Sciences (approval number: IR.TBZMED.REC.1400.1140). All procedures performed involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments. Written informed consent was obtained from all individual participants included in the study.

Declaration of Generative AI and AI-assisted technologies

No generative AI or AI-assisted technologies were used in the preparation of this manuscript.

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