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ORIGINAL PAPER

Hip arthroplasty dislocation risk calculator: evaluation of one million primary implants and twenty-five thousand dislocations with deep learning artificial intelligence in a systematic review of reviews

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Abstract

Purpose This paper aims to provide an overview of the possibility regarding the artificial intelligence application in orthopaedics to predict dislocation with a calculator according to the type of implant (hemiarthroplasty, standard total hip arthroplasty, dual mobility, constrained cups) after primary arthroplasty.

Material and methods Among 75 results for primary arthroplasties, 26 articles were reviews on dislocation after hemiarthroplasty, 40 after standard total hip arthroplasty, seven about primary dual-mobility arthroplasty (DM THA), and two reviews about constrained implants. Although our search method for systematic reviews covers ten years (2012–2022), none for dual mobility was published before 2016, showing a recent explosion of original articles on this subject. A total of 1,069,565 implants and 26,488 dislocations in primary arthroplasties are included in these 75 reviews. We used a supervised learning model in which models assign objects to groups as input and artificial neural network (ANN) with nodes, hidden layers, and output layers. We considered only four implant types as the input layer. We considered the patient's factors (indication for THA, demographics, spine surgery, and neurologic disease) as the second input values (hidden layer). We considered the implant position as the third input (hidden layer) property including head size, combined anteversion, or spinopelvic alignment. Surgery-related factors, approach, capsule repair, etc. were the fourth input values (hidden layer). The output was a post-operative dislocation or not within three months.

Results The accuracy for predicting dislocation with this systematic review was 95%. Dislocation risk, based on the type of implant, was wide-ranging, from 0 to 3.9% (mean 0.31%) for the 3045 DM THA, from 0.2 to 1.2% (overall 0.91%) for the 457 constrained liners, from 1.76 to 4.2% (mean 2.1%) for 895,734 conventional total hip arthroplasties, and from 0.76 to 12.2% (mean 4.5%) for 170,329 hemiarthroplasties. In the conventional THA group, many factors increase the risk of dislocation according to the calculator, and only a few (big head, anterior approach) decrease the risk, but not very significantly. In the hemiarthroplasty group, many factors can increase the risk of dislocation until 30%, but none could decrease the risk. According to the calculator, the DM THA and the constrained liner markedly decreased the risk and were not affected by implant position, spine surgery, and spinopelvic position.

Conclusion To our knowledge, this study is the first to yield an implant-specific dislocation risk calculator that incorporates the patient's comorbidities, the position of components, and surgery factors affecting instability risk.

Keywords Hip dislocation risk calculator · Systematic review of review · Hip fracture · Dual mobility · Constrained liner

Introduction

Numerous characteristics and individual factors linked to the risk of dislocation have been documented in different studies [1–3]. However, it can be difficult for each patient to receive a prognosis about this risk since the risk is rather multifactorial. In particular, it is unclear how implant position and patient-specific factors affect the risks of dislocation. It is also unknown if dual-mobility total hip arthroplasty prevents femoral neck fractures from dislocating

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better than hemiarthroplasty. Lewinnek's safe zone has traditionally been the most significant radiological parameter for evaluating THA stability. However, newer studies have questioned a cup's ability to prevent dislocation if placed inside Lewinnek's safe zone because there was no discernible link between that position and the risk of dislocation [4, 5]. In addition to Lewinnek's safe zone, spinopelvic alignment and the idea of coupled anteversion have both been discussed as factors affecting THA stability [6, 7]. Furthermore, it is unknown that Lewinnek's safe zone remains a predictor for a dual-mobility implant.

Up until now, significant literature has assessed the effects of individual characteristics to evaluate the impact on dislocation [8–11]. Factors are sometimes related only to the patient, other times to factors under the surgeon's control (like implant position) or surgery (primary or revision, anterior or posterior approach).

In reality, looking at the issue in reverse would be less complicated and more helpful: there are only two circumstances (primary or revision) and only four implant types (hemiarthroplasty, standard total hip arthroplasty, dual mobility, constrained cups), but a wide range of patients and surgical techniques. Dislocation is a multifactorial event. An ideal risk prediction model should assess each circumstance with each type of implants based on a wide range of patients. Prediction should also include other causal factors, such as gender, body mass index (BMI), age, neurologic status, and alcohol abuse. Additionally, particular risk factors must be reported, but their importance is not ranked equally.

Quantitative evaluation cannot effectively anticipate the risk through conventional controlled series since only one or a few properties may be examined at a time. We employ machine learning to capture multi-property correlations and utilize all of the data in a database to get around this problem. One type of implant is recent (dual mobility); therefore, we restricted the study to the years 2012 through 2022 to detect the different risks of implants through a systematic review of reviews. As a result, unlike other research, this one is focused on the analysis of various implant rather than the outcomes of patients in a hospital.

The purpose of this study was to develop an implant-specific risk prediction model for dislocation following primary arthroplasty that allows according to the patient factors and operative decisions to discuss a dynamic risk modification after surgery based for example on specific rehabilitation or bracing.

Material and methods

Machine learning selection of data

This systematic review does not need ethics committee approval. Articles in English describing hip dislocations or predicting their development in patients were included in the analysis. An important inclusion criterion was also the clinical focus of the articles. Biomechanics-related articles were excluded in order to provide the study with a traditional clinical orthopedic focus. Articles in languages other than English and publications of other types (reviews, abstracts, comments, conference proceedings, proposals, recommendations) were excluded from the study. We used natural language processing [12] that is a branch of artificial intelligence (AI) allowing interpretation of human language (e.g., written English) to select papers. We selected systematic reviews (Fig. 1) using "disloc," "sublux," "reduc," "reloc," and "displace."

There were 3593 articles on hip arthroplasty dislocation in PubMed between 2012 and 2022. We found 75 results: 26 reviews on dislocation after hemiarthroplasty, 40 reviews after standard total hip arthroplasty, seven reviews about primary dual-mobility arthroplasty, and two reviews about constrained implants.

Data extraction, selection, and splitting

Machine learning algorithms were designed with implant classification and feature extraction to predict dislocation risk when given the implant used in primary arthroplasty. Additionally, a graphical user interface calculator was developed to facilitate clinical use, while ensuring model "explainability."

There are different basic machine learning paradigms: "supervised, unsupervised, and reinforcement learning." To solve classification problems, we used the supervised learning model in which models assign objects to groups of approved clinical classifications. We considered the implant type as the classification group. Random forest and boosting algorithms are categorized under the decision tree models' domain. Conceptually, decision trees are described as a series of nodes, edges, and terminal nodes generated via top-down processes. Nodes are "split" based on the underlying distribution of a given input variable resulting in multiple sub-nodes, as explained in Fig. 2. This process is repeated for multiple iterations as specified by an a priori indicated criterion (i.e., a hyperparameter) ultimately resulting in a predicted output (i.e., a terminal node): In this article, the terminal nodes were dislocation or no dislocation. An artificial neural network (ANN) with nodes is a computing system that is inspired by brain-neuronal networks. The ANN has input layers, hidden layers, and output layers. Each layer has neurons that are connected with those in adjacent layers. Each neuron has its weights in an initial state. The learning process begins when training data is entered in the input layer (type of implants). Data are transferred to "neurons" in the different layers (patients' factors, implant position, surgery factors) until output is reached. The

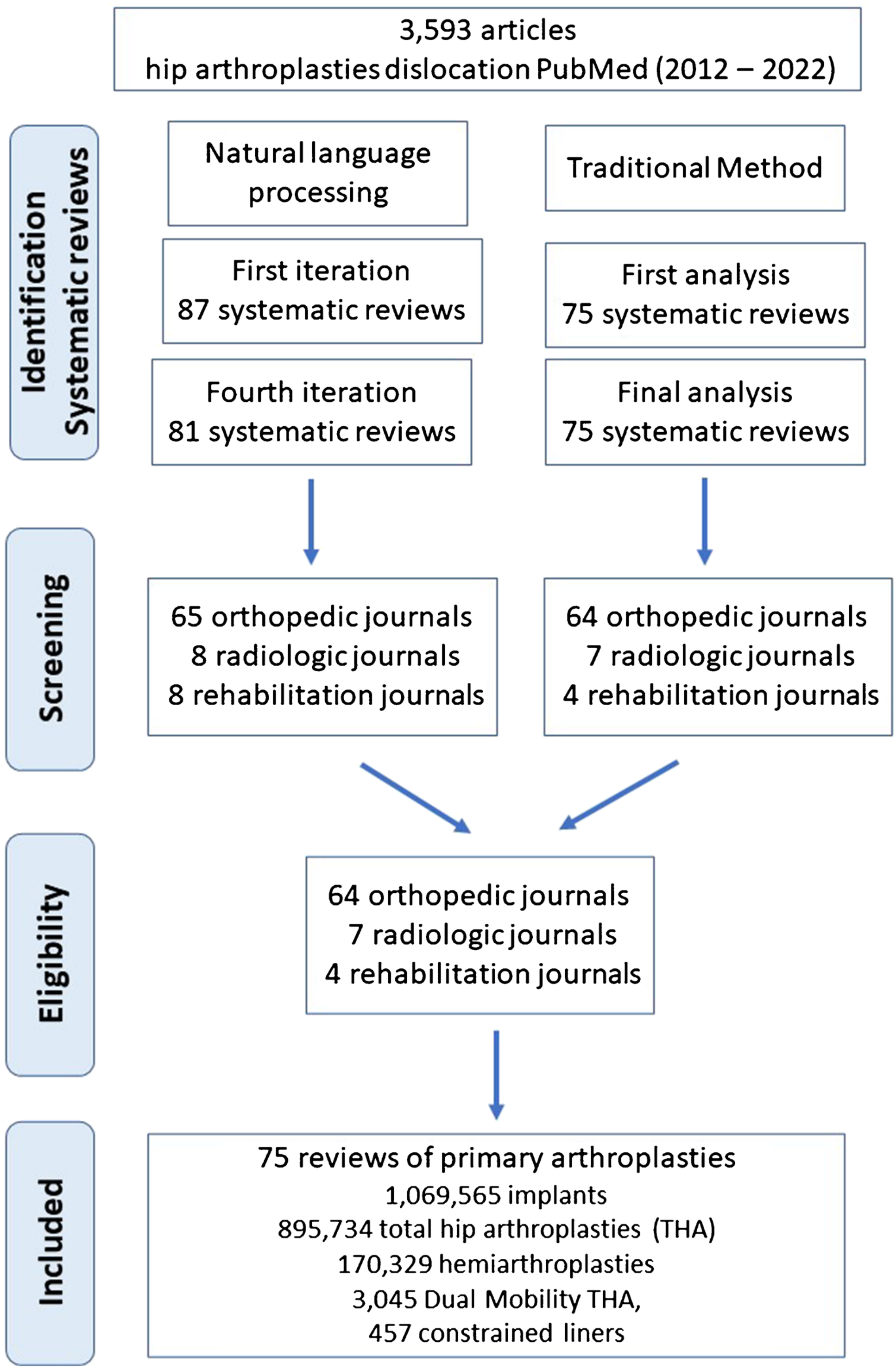
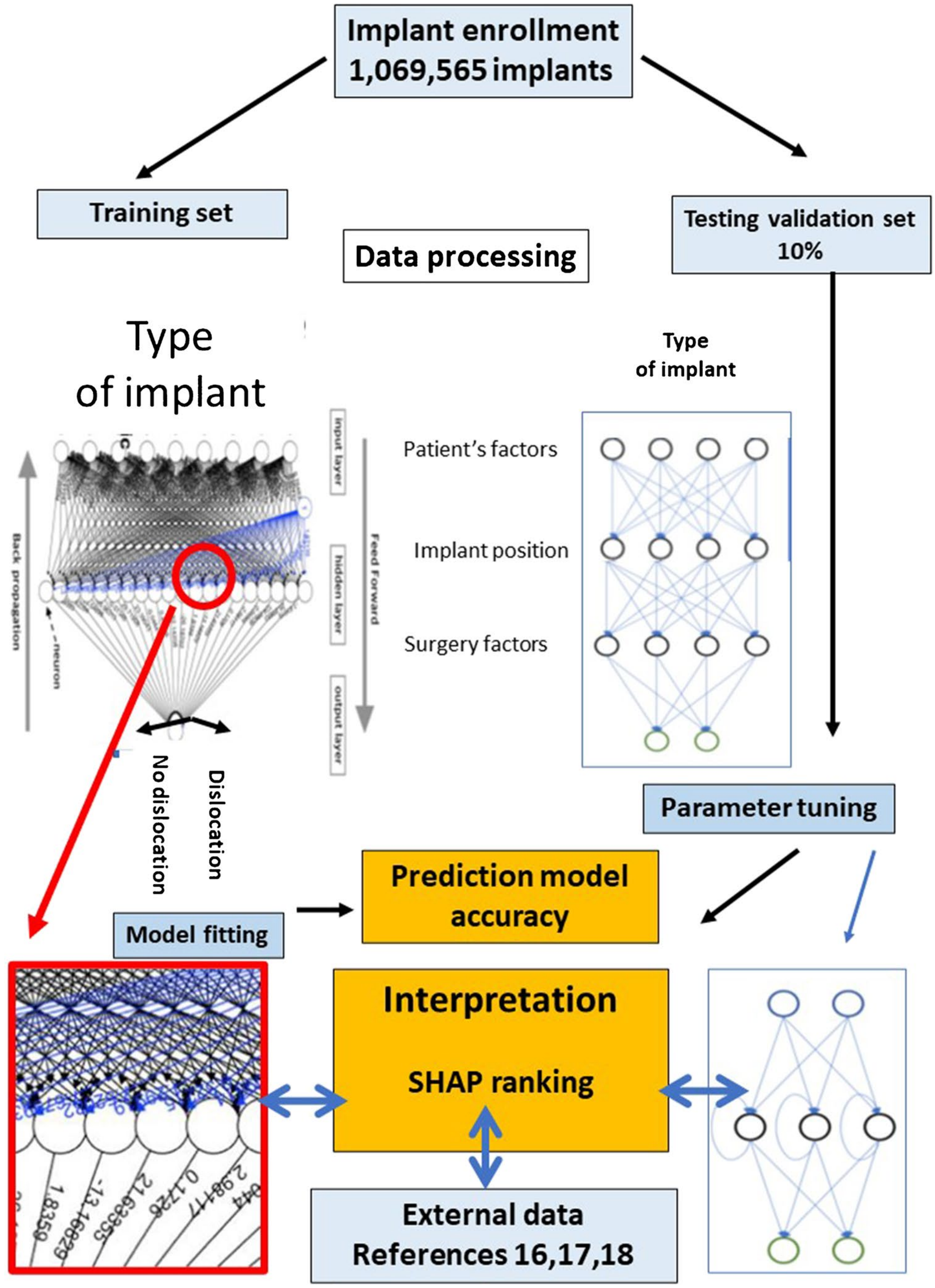


Fig. 1 Flowchart diagram of the selection of review articles

generated output is compared with the provided information (the reality of the disease "dislocation or not"), and an error is generated when the computer's result is different from the reality. The backpropagation technique adjusts connections' weights to decrease the error; then, another cycle with forward processing begins to reach again the output layer.

We analyzed the following categories: age greater than 80 years, a body mass index larger than 32 kg/m^2, a comorbid condition such as neuromuscular disease or cognitive impairment, or previous procedures such as spinal fusion. We considered the patient's factors as the second input values (hidden layer). We considered the

Fig. 2 Flowchart study of dislocation on implants



implant position as the third input (hidden layer) property including position, head size, cup anteversion, the concept of combined anteversion, or spinopelvic alignment. Surgery-related factors, anterior or posterior surgical approach, posterior capsule repair, etc. were the fourth input values (hidden layer). The outcome was post-operative dislocation within three months. A test set of 10% of articles was analyzed in this systematic review, so the same patients with the same distribution of outcomes and surgery dates were randomly selected to test prediction with the learning machine. Another representative test set of external articles not analyzed in this systematic review also were used to test the prediction with external data. We also compared the accuracy of the best performing model in capturing hip dislocation and benchmarked their performance against reality data in some articles with a large database (Fig. 2).

When describing the studied material, we used the broad term "patient data" described in each systematic review. This type of materials includes basic demographic (sex, age, BMI) or/and clinical (anamnesis data, scores on subjective scales, results of objective medical examination) data about patients in the form of text information. The authors of systematic reviews presented the sample volumes in different ways in each review. For the purpose of standardization, we adjusted these values based on the number of implants used in each review. In a number of articles, the total sample size was not specifically indicated, so it was restored indirectly in such cases. Articles that reported primary arthroplasties between 2012 and 2022 were evaluated, yielding 1,069,565 implants whose charts were reviewed to extract the patient's demographics, relevant comorbidities, surgical characteristics, and dislocation (26,488 cases).

Statistical analysis

Data balance

Briefly, the study population was randomly stratified using a 90% and 10% split to create training (algorithm development) and testing (internal validation) sets. This resulted in 6899 dislocations in the training set and 766 dislocations in the testing set. To avoid bias toward the minority, the SMOTE algorithm balanced the training set [13].

Interpretability of the prediction model with ranking the different variables (SHAP)

SHAP, or "SHapley Additive exPlanations," is a technique of machine learning explainability (2017, Lundberg and Lee). The SHAP values [14, 15] consider that the outcome of each combination (or coalition) of factors can be used to rank the importance of a single factor. By way of example, we can imagine a learning model that predicts hip dislocation in hemiarthroplasty, knowing approach (anterior or posterior), obesity, and neurologic pathology (Fig. 3). Imagine, as in Fig. 3, that the percentage of posterior dislocation in the whole series taking all the variables in consideration is 4%. But considering only three factors (approach, obesity, and neurologic pathology), the prediction is 37% of dislocation. As seen (Fig. 3), when connected by an edge, two nodes differ for one feature since the bottom feature has the same feature as the upper one, plus an additional one that the upper one does not have. Therefore, the difference between predictions of two connected nodes is related to the effect of the other feature, called the "marginal contribution" of a component. Applied to our example, the formula (Fig. 3) gives a marginal contribution as follows: SHAP approach = −11.33%; obesity = −2.33%; neurologic disease = +46.66%, which means that in our theoretical example, neurology has the most crucial ranking for prediction of dislocation, obesity has a lower ranking, and approach has no ranking influence compared to neurology and obesity.

Results

Systematic review of systematic reviews on hip dislocations

Articles

There were 3593 articles on hip arthroplasty dislocation in PubMed between 2012 and 2022. A preliminary filter was applied to systematic reviews of primary hip surgery dislocation. We found 75 results: 26 reviews on dislocation after

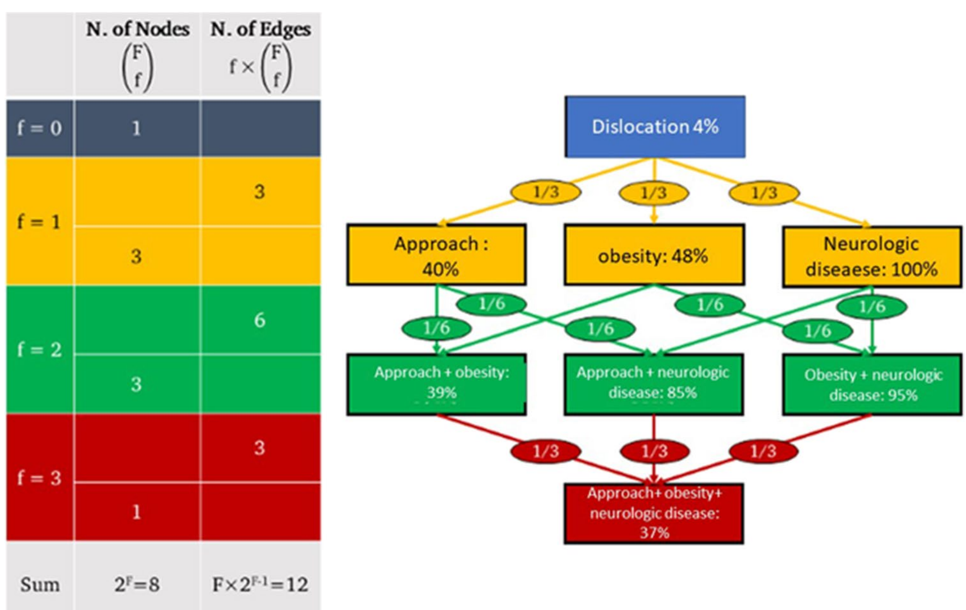


Fig. 3 SHAP values are calculated in a complex model (a neural network) that takes data as input and gives predictions as output

hemiarthroplasty, 40 reviews after standard total hip arthroplasty, seven reviews about primary dual-mobility arthroplasty, and two reviews about constrained implants. Although a ten year time covered the search strategy, no review for dual mobility was published before 2016, indicating a recent increase in publications in this field.

Implants and dislocations

A total of 1,069,565 implants and 26,488 dislocations in primary arthroplasties are included in these 75 reviews.

A total of 3045 DM THA was included in the seven systematic reviews for dual-mobility implants in primary arthroplasty. The mean rate of dislocation following DMC-THA ranged from 0 to 3.9% (overall incidence was 0.31% by meta-analysis), with a theoretical number of nine dislocations. In summary, this represents 435 implants per review and one dislocation per review.

A total of 170,329 hemiarthroplasties were involved in 26 systematic reviews, with a dislocation rate that ranged between 0.76 and 12.2% (overall incidence was 4.5% by meta-analysis) with a theoretical number of 7665. In summary, this represents 6551 implants per review and 295 dislocations per review.

A total of 457 constrained liners were involved in two systematic reviews, with a dislocation rate that ranged between 0.2 and 1.2% (overall incidence was 0.91% by meta-analysis), with a theoretical number of four dislocations. In summary, this represents 228 implants per review and two dislocations per review.

A total of 895,734 total hip arthroplasties were involved in 40 systematic reviews, with a dislocation rate that ranged between 1.76 and 4.2% (overall incidence was 2.1% by meta-analysis) with a theoretical number of 18,810. In summary, this represents 22,393 implants per review and 470 dislocations per review.

Accuracy of research of dislocation with natural language processing

Identification of the papers was obtained after four iterations of the machine learning system (Fig. 1). Compared to the traditional method of reviewing (selection of 75 papers), the machine learning-assisted reviewing was not significantly different ($p = 0.08$) in selecting the papers (81 papers). The machine learning reviewing picked up the relevant papers in 65 orthopaedic journals, eight radiologic journals, and eight rehabilitation journals. After traditional screening, only 75 systematic reviews were kept in 64 orthopaedic journals, seven radiologic journals, and four rehabilitation journals (Fig. 1).

Orthopaedic journals

Natural language processing performed well in classifying orthopaedic journals for systematic review for dislocation. However, it struggled during the first iteration in classifying the "dislocation" in some other form of dislocation than arthroplasty, e.g., dislocated fracture fragments, or, in articles where the status of dislocation was defined as in the text, "no dislocation," where the word "no" comes immediately before "dislocation." In contrast, when "no fracture or dislocation" is present, the model must relate "no" to "dislocation." The system only made one misclassification where the dislocation was described in an atypical fashion—including uncommon terms such as "dislocated *hemiprosthesis*" and "*posterosuperior* dislocation," which only appeared in one article among 65 reviews in orthopaedic journals.

Radiologic journals

Natural language processing achieved high performance in radiologic journals, classifying "dislocation" with only one misclassification overall (7 correct out of 8 subsets). One misclassification was related to the term "dislocation and displacement." Although the implant was dislocated, the term used in the article was displacement, and the language misclassified this term as "no dislocation."

Rehabilitation journals

They generally achieved lower performance classifying with errors on anatomic sites including clinical shoulder dislocation or other sites due to some articles with absence of term "hip" and arthroplasty. These models also could not distinguish between "no dislocation" and "evidence of previous dislocation" and misclassified this note as "no dislocation," resulting in four mistakes among eight subsets.

Prediction of rate of dislocations for each implant group with systematic reviews

A total of 1,069,565 implants with 3045 DM THA, 457 constrained liners, 170,329 hemiarthroplasties, and 895,734 total hip arthroplasties are included in these 75 reviews of primary arthroplasties. Dual-mobility implants represent only 0.3% of indications in this review. As compared, the frequency of dual-mobility implants is 1.7% in some series and around 20% in some countries [16]. So, use of dual-mobility constructs in the primary setting was relatively rare in this review, suggesting that these implants were used in complex cases and that probably the data are supportive without bias for the low rate of dislocation observed in these reviews as in other series of the literature. The same reasoning can be taken for the constrained liners representing 0.05% of implants in this series.

In principle, the dislocation rate is lower with hemiarthroplasty than with total hip prosthesis. A paradoxical result is obtained here with a two times higher risk of dislocation after hemiarthroplasty (4.5%) compared to the risk after THA (2.1%), with 170,329 hemiarthroplasties and 895,734 total hip arthroplasties; these numbers allow high significance in the difference. Compared to other literature series, the rate of dislocation for conventional THA was similar to the other series of THA in registries or monocentric studies with a large number [17]. Although some small series have a lower risk of dislocation with hemiarthroplasty, when data of systematic reviews are compared to the national cohort of 25,678 patients in the Swedish Hip Arthroplasty Register [18], the dislocation risk is similar with a 5% (2.7% with a direct lateral approach and 7.2% with a posterior approach). In summary, the accuracy in the rate of dislocation proposed for each type of implant with systematic reviews and selected with machine learning appears very high (> 95%).

Risk of dislocation for patients with each implant: ranking factors with SHAP values

The most crucial question for the surgeon and the patient is ranking the different factors and their associations. The SHAP value of each factor (importance of the factor for dislocation) and their ranking (Tables 1, 2, 3, and 4) are represented by the color on the table: the redder the colour, the greater the factor importance; the bluer the colour, the lower the factor importance.

We can immediately notice by comparing the four tables; see that those who have the most red colour concern hemiarthroplasty and conventional total prosthesis. Conversely, the tables concerning dual-mobility and constrained prostheses have less red and more blue; that is to say that for these last two types of implants, the risk of dislocation is much lower.

SHAP values with hemiarthroplasties (Table1)

A total of 170,329 hemiarthroplasties with 7665 dislocations were involved in 26 systematic reviews. The study population was randomly stratified using 153,296 hemiarthroplasties in the training set and 17,033 (10%) in the testing set. There were no statistically significant differences in terms of demographics or data related to hip fracture, or implants between the training and testing sets (Table 2) with a similar dislocation rate (4.5% and 4.6%) in both groups, ranging between 0.76 and 12.2%. Most of the indications were neck fractures, with some osteonecrosis and tumours of the proximal femur (Table 1).

Three factors have a SHAP value higher than 4: neurologic disease (SHAP value 4.3); cognitive impairment 4.5; femoral retroversion 4.3. These factors are associated with a high increase dislocation risk after hemiarthroplasty, with a risk of dislocation of 10% in the best and, in the worst scenario, a 20% risk.

Six factors have a SHAP value higher than 3: age > 80 years (SHAP 3.5); BMI > 32 kg/m^2 (SHAP 3.8); tumours 3.2; alcohol abuse 3.1; spine surgery 3.1; scoliosis 3.4. These factors are associated with an increase in dislocation risk after hemiarthroplasty, with in the best scenario a risk of dislocation of 7% and in the worst scenario a 15% risk.

Factors with a SHAP value higher than 2 or higher than 1 have still dislocation risk, with in the best scenario a risk of dislocation of 5%, and in the worst scenario a 10% risk. These are surgery-specific risk factors or radiologic factors such as leg length, offset, and femoral stem anteversion.

Choice of uni- or bipolar design and the fixation (cement, no cement) had no influence on the risk of dislocation.

The following factor was associated with a decreased dislocation risk: a direct anterior approach versus a posterior approach, while posterior soft-tissue repair had low value.

SHAP values with conventional THA (Table 2)

A total of 895,734 total hip arthroplasties with 18,810 dislocations were involved in 40 systematic reviews; the study population was randomly stratified using 742,438 TKA in the training set and 89,573 (10%) in the testing set, with a dislocation rate similar (2.1% and 2.0%) in both groups, ranging between 1.8 and 6.2%.

Five factors have a SHAP value higher than 4: BMI (> 32 kg/m^2) 4.5; neurologic disease 4.6; cognitive impairment 4.5; a 22-mm head diameter 4.7; femoral retroversion 4.7. These factors are associated with a high increase in dislocation risk after conventional THA, with a risk of dislocation of 5% in the best scenario and a 10% risk in the worst scenario.

Eight factors have a SHAP value higher than 3: these factors are associated with an increase in dislocation risk after conventional THA, with in the best scenario a risk of dislocation of 4% and in the worst scenario a 7% risk.

Many factors had a SHAP value higher than 2 or higher than 1 having a dislocation risk, with in the best scenario a risk of dislocation of 2% and in the worst scenario a 5% risk.

The following factors were significantly associated with an increased dislocation risk after primary THAs: neck fracture, osteonecrosis, or rheumatoid arthritis as the diagnosis for indication of THA. In addition to the surgery factors, review in radiologic journals reported the reconstruction of the rotation center, offset, and leg length. To analyze the influence of cup positioning in Lewinnek's safe zone, the values for cup abduction and anteversion were analyzed, as the risk to have a cup outside of Lewinnek's safe zone. These factors had a SHAP value > 2 confirming the importance of the cup position. However, spine surgery and spinopelvic position have a higher ranking value for dislocation (SHAP > 3).

SHAP values with dual-mobility implant and constrained liner (Tables 3 and 4)

Most factors had a SHAP value ranking < 2, demonstrating the low risk of dislocations with dual mobility (Table 3) for the patients during the first three months. Contrary to conventional

Table 1 SHAP values of predictive factors for dislocation with hemiarthroplasty: the larger the feature value is, the redder the colour, and the smaller the feature is, the bluer the colour

Feature	SHAP value
(1) demographic information:	
Age > 80 Years	3.5
female	2.2
Male	1.3
BMI (> 32 kg/m²)	3.8
(2) Indication:	
Fracture	1.5
Osteonecrosis	2.1
Tumors	3.2
(3) Patient information	
alcohol abuse	3.1
smoking	1.2
corticosteroids	1.4
cardiac disease	2.1
Spine surgery	3.1
Scoliosis	3.4
Neurologic disease	4.3
Cognitive impairment	4.5
(4) surgery factors	
Posterior approach	2.3
Anterior approach	1.5
Capsule repair	1.3
No capsule repair	1.7
(6) Type of hemiarthroplasty	
Unipolar	0.7
Bipolar	0.8
Cemented	0.8
Uncemented	0.9
Collar	0.4
No collar	1.3
(7) position of femoral implant	
Femoral retroversion	4.3
Offset	1.2
Leg length discrepancy	2.5
Hip abnormal rotation	2.4
(10) contralateral hip	
Trochanteric fracture	2.1
Hip fracture	1.4
Previous dislocation	1.2
(11) Thrombophlebitis prevention	
Aspirin	0.2
HBPM	1.2
Coumadin	2.1

arthroplasty, the cup position, spine surgery, and spinopelvic position had a low ranking value for dislocation, confirming the prevention of dislocation linked to impingement with DM. The exception was for DDH, neurologic disease, and tumours. The SHAP values confirm that DM had lower prevention when the dislocation is related to a mechanism of translation (absence of muscle, neurologic disease). In these circumstances (absence of muscle, neurologic disease), the prevention is better with a constrained liner (Table 4).

Contribution of associated factors: dislocation risk calculator

Table 5 summarizes the different principal features of the 4 types of implants.

Case example one

An 81-year-old woman with a BMI of 33 kg/m^2 has a femoral neck fracture (Table 6). She had spine arthrodesis and some cognitive impairment. Surgery was a hemiarthroplasty. Her absolute risk of dislocation with the hemiarthroplasty is around 20% even if surgery is perfectly done, and there is no way to decrease this risk. The total SHAP value of the risks is 20.9 (2.2 + 3.5 + 3.8 + 1.5 + 3.1 + 4.5 + 2.3).

The same lady operated with a conventional THA has a total SHAP value of 25.1 (2.2 + 3.8 + 4.5 + 3.2 + 3.6 + 4.9 + 2.9). Her absolute risk of dislocation is higher than with a hemiarthroplasty, whatever the quality of the surgery.

With a DM THA, the SHAP value of the risk is 2 (less than 5), with a risk of dislocation of less than 2%. The risk increases if the anticoagulation used Coumadin (SHAP 4.2) since DM implant does not prevent dislocation related to haematoma very well. This will not be the case with a constrained liner; the SHAP value remains at 1 with a risk of dislocation of 0.5%.

Case example two

A 35-year-old patient with hip osteonecrosis related to alcohol abuse has a conventional THA performed with a posterior

Table 2 SHAP values of predictive factors for dislocation with conventional THA: the larger the feature value is, the redder the colour, and the smaller the feature is, the bluer the colour

(1) demographic information:	
Age > 80 Years	3.8
Age< 40 years	2.8
female	2.2
Male	1.3
BMI (> 32 kg/m²)	4.5

(2) indication of THA:	
Osteoarthritis	0.8
DDH	3.5
Rheumatoid arthritis	2.9
Fracture	3.2
Osteonecrosis	2.6
Tumors	3.8

(3) Patient information	
alcohol abuse	3.8
smoking	1.2
corticosteroids	1.4
cardiac disease	2.4
Hip mobility	1.4
Spine surgery	3.6
Scoliosis	3.9
Neurologic disease	4.6
Cognitive impairment	4.9

(4) surgery factors	
Posterior approach	2.9
Anterior approach	1.5
Capsule repair	0.6
No capsule repair	1.7

(5) head diameter	
22mm	4.7
28mm	3.8
32mm	2.2
36 mm	1.2

(6) position of femoral implant	
Femoral retroversion	4.7
Offset	1.2
Leg length discrepancy	2.9
Hip abnormal rotation	2.8

(7) cup position	
Anteversion<10°	2.6
Abduction >50°	2.8
Outside Lewinnek's safe zone	2.4
Pelvis obliquity	1.9

(8) Type of arthroplasty	
Cemented	1.3
Uncemented	2.4
Collar	0.4
No collar	1.3

(9) Bearing surfaces	
Metal /PE	0.3
Ceramic/ME	0.2
Ceramic/ Ceramic	0.3

(10) contralateral hip	
Normal	0.1
Osteoarthritis	0.5
Previous dislocation	1.3

(11) Thrombophlebitis prevention	
Aspirin	0.2
HBPM	1.2
Coumadin	2.8

approach and with a 28-mm head diameter; the cup is outside Lewinnek's safe zone. The total SHAP value of the risks is 19.6 (2.8 + 1.3 + 2.6 + 3.8 + 2.9 + 3.8 + 2.4), representing an absolute risk of dislocation of 15%. Avoiding the posterior approach, changing the 28-mm to 36-mm head diameter, and avoiding the malposition of the cup decrease the SHAP value to 10, with a lower risk of dislocation of 5%. With a dual-mobility implant, the SHAP value is less than 0.5%.

Discussion

In some systematic review processes, screening more than 1000 publications is expected due to the exponential growth in the number of papers on PubMed [19], which is time-consuming and subject to error. The evaluation process has been enhanced using artificial intelligence [20]. According to our findings, the systematic review approach using machine learning was as effective as the screening procedure. Orthopedic surgery for conducting a systematic review screening procedure produced results that were comparable to those of the other fields where it had previously been evaluated [20, 21]. The system's effectiveness in comparison to the conventional screening procedure depends on the query. The study has limitations. First, it is impossible to categorize how challenging the screening scenarios are. Second, we did not compare every available machine learning-assisted systematic review platform. In the second section, machine learning was used to combine clinical, surgical, and postoperative radiograph data to assess the risk of dislocation based on the type of implant. This allowed designing a "risk calculator."

Table 3 SHAP values of predictive factors for dislocation with dual-mobility THA: the larger the feature value is, the redder the colour, and the smaller the feature is, the bluer the colour

(1) demographic information:	
Age > 80 Years	0.1
Age< 40 years	0.2
female	0.3
Male	0.2
BMI (> 32 kg/m^2)	1.5
(2) cause of THA:	
Osteoarthritis	0.1
DDH	2.5
Rheumatoid arthritis	0.2
Fracture	0.3
Osteonecrosis	0.2
Tumors	3.1
(3) Patient information	
alcohol abuse	1.5
smoking	0.2
corticosteroids	0.2
hip mobility	0.3
cardiac disease	0.4
Spine surgery	1.1
Scoliosis	1.3
Neurologic disease	2.3
Cognitive impairment	0.2
(4) surgery factors	
Posterior approach	0.2
Anterior approach	0.1
Capsule repair	0.3
No capsule repair	0.2
(5) head diameter	
22mm	0.2
28mm	0.3
(6) position of femoral implant	
Femoral retroversion	0.8
Offset	0.2
Leg length discrepancy	0.5
Hip abnormal rotation	0.1
(7) cup position	
Anteversion <10°	0.4
Abduction > 50°	1.3
Outside Lewinnek's safe zone	1.1
Pelvis obliquity	1.2
(8) Bearing surfaces	
Metal /PE	0.3
Ceramic/PE	0.4
(9) Type of hemiarthroplasty	
Cemented	0.3
Uncemented	0.4
Collar	0.4
No collar	0.6
(10) contralateral hip	
Normal	0.1
Osteoarthritis	0.1
(11) Thrombophlebitis prevention	
Aspirin	0.2
HBPM	1.2
Coumadin	2.1

The patient's recovery following arthroplasty is significantly impacted by an implant dislocation, a serious post-operative complication. While the dislocation rate has been estimated to be around 2% in recent literature, the re-dislocation rate following a closed reduction is estimated to be as high as 20–40% [22]. The first step in lowering the risk of dislocation is to understand what each implant gives as benefit or inconvenient and what the patient literally brings to the risk in terms of age, sex, body mass index (BMI), indication for surgery, and related medical issues. Advice given to patients following surgery is always useful. This is crucial for some people who are at risk for a new anaesthetic and have cardiac comorbidities. Patients who experienced at least one hip prosthesis dislocation incident [23] had statistically higher mortality rates (from 16.0 to 24.6% at 90 days and 29.5 to 44.7% at 1 year). Even greater fatality rates were seen in recurrent dislocations [23].

The advantage of the risk calculator described here is that it predicts the risk of dislocation according to the implant, the patient, and the post-operative radiograph. Temporary immobilization and the use of motion-restricting hip braces [24, 25] after surgical treatment are two ways to lower the risk of re-dislocation and promote joint stability after surgery. Hip braces also help patients become aware of how to minimize their range of motion (ROM) and movements that could cause joint dislocation. Since it is impractical to brace every patient, the genuine query is as follows: who needs abduction bracing after hip arthroplasty?

High dislocation rate is unsatisfying with hemi-arthroplasties in this series as already reported [26]. Results also suggest that many patients' results cannot be improved because it is impossible to lower SHAP values in most situations. Most of the indications are in neck fractures of old patients. We saw in case example 1

Table 4 SHAP values of predictive factors for dislocation with constrained THA: the larger the feature value is, the redder the colour, and the smaller the feature is, the bluer the colour

(1) demographic information:	
Age > 80 Years	0.1
Age< 40 years	0.2
female	0.3
Male	0.2
BMI (> 32 kg/m^2)	0.1
(2) cause of THA:	
Osteoarthritis	0.1
DDH	1.3
Rheumatoid arthritis	0.2
Fracture	0.2
Osteonecrosis	0.2
Tumors	0.8
(3) Patient information	
alcohol abuse	0.9
smoking	0.2
corticosteroids	0.2
hip mobility	0.3
cardiac disease	0.4
Spine surgery	1.1
Scoliosis	0.7
Neurologic disease	0.8
Cognitive impairment	0.2
(4) surgery factors	
Posterior approach	0.2
Anterior approach	0.1
Capsule repair	0.3
No capsule repair	0.2
(5) head diameter	
22mm	0.2
28mm	0.3
(6) position of femoral implant	
Femoral retroversion	0.8
Offset	0.2
Leg length discrepancy	0.5
Hip abnormal rotation	0.1
(7) cup position	
Anteversion <10°	0.4
Abduction > 50°	0.6
Outside Lewinnek's safe zone	0.4
Pelvis obliquity	0.4
(8) Bearing surfaces	
Metal /PE	0.3
(9) Type of hemiarthroplasty	
Cemented	0.3
Uncemented	0.4
Collar	0.4
No collar	0.6
(10) contralateral hip	
Normal	0.1
Osteoarthritis	0.1
(11) Thrombophlebitis prevention	
Aspirin	0.2
HBPM	0.4
Coumadin	0.3

that there is a very high risk, and regardless of the level of surgery, this risk will not go down. Furthermore, it should be noted that these patients do not have the time or chance to look for assistance at another hospital or an expert arthroplasty surgeon. When hemiarthroplasty is carried out, these ideal circumstances are typically not present. Young surgeons in numerous countries often carry out hemiarthroplasties. An abduction brace needs to be recommended in this population to prevent dislocation because the risk of mortality is increased in these patients, following dislocation. Another option would be to suggest a dual-mobility implant, which would come at an additional cost.

Dislocation is one the most frequent complication following primary THA and is one of the first reasons for revision surgery. Most dislocations occur right away after surgery and are accompanied by severe pain, loss of limb function, patient dissatisfaction, need for new anaesthesia for closed reduction, and occasionally death; it should be useful to know is at risk of dislocation. With total hip arthroplasty, most surgeons suggest to patients an abduction brace to avoid adduction and limit hip flexion following a first-time dislocation. Our risk calculator makes it possible to choose patients who require prevention with bracing by identifying those who are at risk of dislocation after primary THA. A brace should be discussed with the patient if the SHAP value on the post-operative radiographs is greater than 15.

Dual-mobility implants and constrained liners do not need bracing, since the risk of dislocation is lower than 0.5% with the calculator as in many series [27]. One exception can be discussed, a surgery performed for bone tumor and absence of muscle after surgery. One of the most important points is that the cup position, the safe zone described by Lewinnek, and the spine stiffness are not a risk of dislocation with a dual-mobility implant,

Table 5 Dislocation risk calculator

HEMIARTHROPLASTY

(1) Demographic

Age > 80 Years	3.5
female	2.2
Male	1.3
BMI (> 32 kg/m²)	3.8

(2) Indication:

Fracture	1.5
Osteonecrosis	2.1
Tumors	3.2

(3) Patient information

alcohol abuse	3.1
smoking	1.2
corticosteroids	1.4
cardiac disease	2.1
Spine surgery	3.1
Scoliosis	3.4
Neurologic disease	4.3
Cognitive impairment	4.5

(4) surgery factors

Posterior approach	2.3
Anterior approach	1.5
Capsule repair	1.3
No capsule repair	1.7

(5) femoral implant

retroversion	4.3
Offset	1.2
length discrepancy	2.5
abnormal rotation	2.4

(6) contralateral hip

Trochan fracture	2.1
Hip fracture	1.4
Previous dislocation	1.2

TOTAL:	Dislocation
SHAP ≤ 1	<0.5%
1<SHAP≤5	2%
5<SHAP≤10	5%
10<SHAP≤15	10%
15<SHAP≤20	15%
20<SHAP≤25	20%
25<SHAP<30	30%

CONVENTIONAL THA

(1) Demographic

Age > 80 Years	3.8
Age< 40 years	2.8
female	2.2
BMI (> 32 kg/m²)	4.5

(2) indication of THA:

DDH	3.5
Rheumatoid arthritis	2.9
Fracture	3.2
Osteonecrosis	2.6
Tumors	3.8

(3) Patient information

alcohol abuse	3.8
cardiac disease	2.4
Spine surgery	3.6
Scoliosis	3.9
Neurologic disease	4.6
Cognitive impairment	4.9

(4) surgery factors

Posterior approach	2.9

(5) head diameter

22mm	4.7
28mm	3.8
32mm	2.2

(6) femoral implant

retroversion	4.7
length discrepancy	2.9
abnormal rotation	2.8

(7) cup position

Anteversion<10°	2.6
Abduction >50°	2.8
Outside Lewinnek's	2.4

TOTAL:	Dislocation
SHAP ≤ 1	<0.5%
1<SHAP≤5	2%
5<SHAP≤10	5%
10<SHAP≤15	10%
15<SHAP≤20	15%
20<SHAP≤25	20%
25<SHAP<30	30%

DUAL MOBILITY

Demographic

BMI (> 32 kg/m²)	1.5

cause of THA:

DDH	2.5
Tumors	3.1

Patient information

alcohol abuse	1.5
Spine surgery	1.1
Scoliosis	1.3
Neurologic disease	2.3

surgery factors

Posterior approach	0.2
Anterior approach	0.1
Capsule repair	0.3
No capsule repair	0.2

head diameter

22mm	0.2
28mm	0.3

cup position

Abduction > 50°	1.3
Outside Lewinnek's	1.1
Pelvis obliquity	1.2

Thrombophlebitis

HBPM	1.2
Coumadin	2.1

TOTAL:	Dislocation
SHAP ≤ 1	<0.5%
1<SHAP≤5	2%
5<SHAP≤10	5%
10<SHAP≤15	10%
15<SHAP≤20	15%
20<SHAP≤25	20%
25<SHAP<30	30%

CONSTRAINED

demographic

Age > 80 Years	0.1
Age< 40 years	0.2
female	0.3
Male	0.2
BMI (> 32 kg/m²)	0.8

(2) cause of THA:

Osteoarthritis	0.1
DDH	1.3
Rheumatoid arthritis	0.2
Fracture	0.3
Osteonecrosis	0.2
Tumors	0.8

(3) Patient information

alcohol abuse	0.9
smoking	0.2
corticosteroids	0.2
hip mobility	0.3
cardiac disease	0.4
Spine surgery	1.1
Scoliosis	0.7
Neurologic disease	0.8
Cognitive impairment	0.2

(4) surgery factors

Posterior approach	0.2
Anterior approach	0.1

(5) head diameter

22mm	0.2
28mm	0.3

TOTAL:	Dislocation
SHAP ≤ 1	<0.5%
1<SHAP≤5	2%
5<SHAP≤10	5%
10<SHAP≤15	10%
15<SHAP≤20	15%
20<SHAP≤25	20%
25<SHAP<30	30%

Table 6 Case example 1

HEMIARTHROPLASTY

(1) Demographic	
Age > 80 Years	3.5
female	2.2
Male	1.3
BMI (> 32 kg/m^2)	3.8

(2) Indication:	
Fracture	1.5
Osteonecrosis	2.1
Tumors	3.2

(3) Patient information	
alcohol abuse	3.1
smoking	1.2
corticosteroids	1.4
cardiac disease	2.1
Spine surgery	3.1
Scoliosis	3.4
Neurologic disease	4.3
Cognitive impairment	4.5

(4) surgery factors	
Posterior approach	2.3
Anterior approach	1.5
Capsule repair	1.3
No capsule repair	1.7

(5) femoral implant	
retroversion	4.3
Offset	1.2
length discrepancy	2.5
abnormal rotation	2.4

(6) contralateral hip	
Trochan fracture	2.1
Hip fracture	1.4
Previous dislocation	1.2

TOTAL:	Dislocation
SHAP ≤ 1	<0.5%
1<SHAP≤5	2%
5<SHAP≤10	5%
10<SHAP≤15	10%
15<SHAP≤20	15%
20<SHAP≤25	20%
25<SHAP<30	30%

CONVENTIONAL THA

(1) Demographic	
Age > 80 Years	3.8
Age< 40 years	2.8
female	2.2
BMI (> 32 kg/m^2)	4.5

(2) indication of THA:	
DDH	3.5
Rheumatoid arthritis	2.9
Fracture	3.2
Osteonecrosis	2.6
Tumors	3.8

(3) Patient information	
alcohol abuse	3.8
cardiac disease	2.4
Spine surgery	3.6
Scoliosis	3.9
Neurologic disease	4.6
Cognitive impairment	4.9

(4) surgery factors	
Posterior approach	2.9

(5) head diameter	
22mm	4.7
28mm	3.8
32mm	2.2

(6) femoral implant	
retroversion	4.7
length discrepancy	2.9
abnormal rotation	2.8

(7) cup position	
Anteversion<10°	2.6
Abduction >50°	2.8
Outside Lewinnek's	2.4

TOTAL:	Dislocation
SHAP ≤ 1	<0.5%
1<SHAP≤5	2%
5<SHAP≤10	5%
10<SHAP≤15	10%
15<SHAP≤20	15%
20<SHAP≤25	20%
25<SHAP<30	30%

DUAL MOBILITY

Demographic	
BMI (> 32 kg/m^2)	1.5

cause of THA:	
DDH	2.5
Tumors	3.1
Fracture	0.3

Patient information	
alcohol abuse	1.5
Spine surgery	1.1
Scoliosis	1.3
Neurologic disease	2.3

surgery factors	
Posterior approach	0.2
Anterior approach	0.1
Capsule repair	0.3
No capsule repair	0.2

head diameter	
22mm	0.2
28mm	0.3

cup position	
Abduction > 50°	1.3
Outside Lewinnek's	1.1
Pelvis obliquity	1.2

Thrombophlebitis	
HBPM	1.2
Coumadin	2.1

TOTAL:	Dislocation
SHAP ≤ 1	<0.5%
1<SHAP≤5	2%
5<SHAP≤10	5%
10<SHAP≤15	10%
15<SHAP≤20	15%
20<SHAP≤25	20%
25<SHAP<30	30%

CONSTRAINED

Demographic	
Age > 80 Years	0.1
Age< 40 years	0.2
female	0.3
Male	0.2
BMI (> 32 kg/m^2)	0.1

(2) cause of THA:	
Osteoarthritis	0.1
DDH	1.3
Rheumatoid arthritis	0.2
Fracture	0.2
Osteonecrosis	0.2
Tumors	0.8

(3) Patient information	
alcohol abuse	0.9
smoking	0.2
corticosteroids	0.2
hip mobility	0.3
cardiac disease	0.4
Spine surgery	1.1
Scoliosis	0.7
Neurologic disease	0.8
Cognitive impairment	0.2

(4) surgery factors	
Posterior approach	0.2
Anterior approach	0.1

(5) head diameter	
22mm	0.2
28mm	0.3

TOTAL:	Dislocation
SHAP ≤ 1	<0.5%
1<SHAP≤5	2%
5<SHAP≤10	5%
10<SHAP≤15	10%
15<SHAP≤20	15%
20<SHAP≤25	20%
25<SHAP<30	30%

according to our risk dislocation calculator. It is unlikely that there is a cup position target that surgeons can use for all patients for a conventional THA [28]. Functional zones according to the spine might be considered separately and targeted with robotic to avoid impingement with traditional THA. Another solution is using a dual-mobility THA that allows great mobility without dislocation regardless of the spine's position [29, 30].

Conclusion

In this study, we created a precise model to calculate hip dislocation risk following primary hip surgery using information from medical literature. The most frequently used words in medical papers served as the basis for the model constructed for this study. In some circumstances, we identified a significant risk of dislocation, allowing us to specifically target those patients who need abduction bracing following hip arthroplasty.

Temporary immobilization and the use of motion-restricting hip braces after surgical treatment are two ways to lower the risk of re-dislocation and promote joint stability. Hip braces also help patients become aware of minimizing their range of motion (ROM) and movements that could cause joint dislocation.

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Author contribution Data collection (PH, OB) and redaction (PH, PC).

Data availability Available on reasonable request from PubMed.

Code availability None.

Declarations

Ethical approval The study does not involve individual patient data, and hence, ethics approval is not needed.

Consent to participate Not applicable.

Consent for publication Authors agree to publish the manuscript.

Competing interests The authors declare no competing interests.

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