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Research Article

Prediction Model for Contralateral Hip Dislocation in Cerebral Palsy Patients with Unilateral Hip Dislocation: A Scoring System to Guide Decision Making

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Abstract

BACKGROUND: Cerebral palsy (CP) patients commonly present with unilateral hip dislocation. However, the decision for concurrent prophylaxis surgery on the contralateral hip in this condition is still controversial.

AIM: This study aims to explore the prognostic factors for contralateral hip dislocation and develop a scoring system.

MATERIALS AND METHODS: Data on CP patients with unilateral hip dislocation between January 2005 to January 2019 were reviewed. We explored the difference of preoperative parameters between the group in which the contralateral hip is eventually dislocated or remains stable. A multivariable logistic regression analysis was performed to develop a model for predicting contralateral hip dislocation.

RESULTS: Seven of included 30 patients (23.3%) developed contralateral hip dislocation. Pre-operative contralateral hip's Reimer's Migration Index (RMI), Acetabular Index (AI), Lateral Center Edge Angle of Wiberg (CEA), and Pelvic obliquity (PO) were significantly different (p = 0.049, 0.019, 0.030 and 0.038 respectively). The multivariable logistic regression analysis reveals that RMI > 25% (mOR 36.66, 95% CI 1.13–1185.50, p = 0.042) and age <9 years old (mOR = 22.55, 95% CI 0.76–665.37, p = 0.071) are significant predictors. Both parameters were included in the model, which revealed an AuROC of 0.84 (95% CI 0.69–0.99). Each factor was assigned a score of 1. There was no contralateral hip displacement in patients with a score of 0. Two out of 15 patients (28.6%) with a score of one developed contralateral hip displacement. Five out of eight (71.4%) patients with a score of 2 developed contralateral hip dislocation.

CONCLUSIONS. Significant predictors for contralateral hip dislocation in CP patients are RMI >25% and age <9 years old. The proposed scoring system might help guide the surgeon's decision to perform contralateral prophylactic surgery.

Keywords: orthopedics; cerebral palsy; hip dislocation; scoring method; children.

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Научная статья

Модель прогнозирования вывиха контралатерального бедра у пациентов с церебральным параличом и односторонним вывихом бедра: система оценки для принятия решений

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Аннотация

Актуальность. В комплексе проблем, выявляемых у пациентов с церебральным параличом, часто встречается односторонний вывих бедра. Однако вопрос необходимости одновременного превентивного оперативного вмешательства на контралатеральном бедре при центральном параличе по-прежнему вызывает дискуссии.

Цель — определение прогностических факторов развития вывиха контралатерального бедра и разработка системы оценки для принятия решения об оперативном лечении.

Материалы и методы. За период с января 2005 г. по январь 2019 г. проведен обзор пациентов с церебральным параличом и односторонним вывихом бедра. Обнаружено различие показателей до операции в группе пациентов, у которых впоследствии развился вывих контралатерального бедра или у которых контралатеральный тазобедренный сустав остался стабильным. Для разработки модели прогнозирования вывиха контралатерального бедра мы провели многофакторный анализ методом логистической регрессии.

Результаты. Из 30 пациентов, включенных в исследование, вывих контралатерального бедра развился у 7 человек (23,3 %). У этих пациентов наблюдались значимые различия показателей миграционного индекса Реймерса (RMI), ацетабулярного индекса, латерального центрально-краевого угла Виберга и перекоса таза до операции (p = 0,049, 0,019, 0,030 и 0,038 соответственно). В ходе многофакторного анализа с применением логистической регрессии мы обнаружили, что значимыми прогностическими факторами являются RMI >25 % (медиана отношения шансов 36,66, 95 % ДИ 1,13–1185, 50, p = 0,042) и возраст <9 лет (медиана отношения шансов 22,55, 95 % ДИ 0,76–665,37, p = 0,071). Оба параметра были включены в модель, в результате площадь под ROC-кривой составила 0,84 (95 % ДИ 0,69–0,99). Каждому фактору присваивали 1 балл. У пациентов с баллом 0 смещение головки контралатеральной бедренной кости отсутствовало. Среди 15 пациентов с баллом 1 смещение головки контралатеральной бедренной кости произошло у двух человек (28,6 %). Из 8 пациентов с баллом 2 вывих контралатерального бедра развился у 5 человек (71,4 %).

Выводы. Значимыми прогностическими факторами развития вывиха контралатерального бедра у пациентов с церебральным параличом являются RMI >25 % и возраст <9 лет. Предлагаемая система балльной оценки может помочь хирургам принять решение о проведении превентивного оперативного вмешательства на контралатеральном бедре.

Ключевые слова: ортопедия; церебральный паралич; вывих бедра; метод балльной оценки; дети.

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BACKGROUND

Cerebral palsy (CP) is a group of disorders mainly affecting motor function. It is caused by a non-progressive brain lesion while the motor impairment is progressive. It is a considerably common condition with a prevalence of 1:1000 live birth [1]. In addition, hip subluxation and dislocation are commonly encountered in this condition, especially in a patient who has a higher grade of the Gross Motor Function Classification System (GMFCS) [2].

The recommended surveillance and treatment algorithm have been outlined in many guidelines [3, 4]. Early detection and preventative soft tissue surgery in hip-at-risk patients are recommended to prevent further hip displacement [5]. If the hip is dislocated, it is commonly treated by proximal femur varus derotation osteotomy (VDRO). Reconstruction of the dislocated hip can decrease the migration index and prevent femoral head deformation in the long term [6]. Preoperative Reimer's migration index (RMI) is a significant predictor of outcomes [7]. Furthermore, combining pelvic osteotomy with VDRO may provide a better chance of achieving a painless and stable hip, even when the surgery is performed after triradiate cartilage closure [8, 9].

The natural history of the contralateral hip reveals a varying rate of progression from as low as 4% to 74% [1, 10]. Several factors were associated with the progression of the contralateral hip. These factors include reversal of pelvic obliquity, larger contralateral hip RMI, younger age, higher Acetabular Index (AI), and non-ambulatory status [11–15]. Thus, the management of the contralateral hip is still controversial.

AIM. Therefore, we aim to explore the prognosis factors for contralateral hip dislocation and establish a prediction model. This model could help the surgeon decide to perform a concurrent VDRO of the contralateral hip.

MATERIALS AND METHODS

Research design

This is an institutional review board-approved, retrospective study on all CP patients with unilateral hip dislocation during a 14-year period from January 2005 to January 2019.

Conformity criteria

Relevant data were collected from chart records and radiographic images. Demographic data, including age, body weight, and body height, were recorded at the time that the dislocation was detected. In addition, preoperative GMFCS classification and topographic classification were recorded.

Radiographic parameters, which included Reimer's migration index (RMI), acetabular index (AI), center edge angle (CEA), neck shaft angle (NSA), and pelvic obliquity (PO), were measured both pre-operatively and every post-operative visit. RMI was measured with a classical method described by Reimers [16]. AI and CEA were measured using the lateral end of the acetabular sourcil as a landmark [17]. PO was measured with the O'Brien method [18], and a positive value means that the dislocated hip is higher than the contralateral side.

Treatment protocol

We have four pediatric orthopaedists who actively worked during these 14 years. Patients who had a unilateral dislocated hip were offered surgical reduction. The definition of unilateral dislocation is when the patient has one hip with RMI >40% while the contralateral hip has RMI ⩽40%. If the patients and parents agreed with the treatment plan, VDRO with or without pelvic osteotomy would be performed. However, some of them denied surgery. The decision to perform concomitant pelvic osteotomy (either Pemberton or Dega osteotomy) is based on each surgeon's appreciation of the degree of acetabular dysplasia. Adductor tenotomy was performed in all cases within the same operation for the contralateral hip. The patients were placed in a hip spica cast for six weeks post-operatively in abduction. The radiograph was taken at two weeks, six weeks, three months, six months, and then yearly until skeletal maturity (defined by Risser stage 5 from the X-ray).

Outcome measurement

The hip which is dislocated at the first presentation is identified as the "dislocated hip". The other side is recognized as a "contralateral hip". Hip dislocation is defined as having an RMI >40% because most hips with an RMI above this threshold will progress if the patient does not receive operative treatment [10]. Patients were divided into two groups. The group in which the contralateral hip eventually dislocated is designated as the "dislocated group". The remaining patients are designated as the "non-dislocated" group. Each preoperative parameter was compared between these two groups.

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Statistical analysis

Data distribution patterns were examined by histogram and Shapiro-Wilk test. Normally distributed continuous data were presented with mean ± SD and tested with Independent T-test. Non-normally distributed continuous variables were presented with median and interquartile range (IQR) and were tested with the Mann-Whitney U-test. Categorical data were presented with count and percentage and tested with Fisher's exact probability test. Statistical significance was set at $p < 0.05$. All statistical analyses were performed by using STATA 16 (StataCorp, LLC, College Station, TX, USA) Multivariable logistic regression analysis was performed to identify the prognostic factors from candidate predictors such as age, disease severity, and radiographic parameters. Subsequently, the prediction model was then developed using a step-wise backward elimination algorithm to include only variables with statistically significant predictive ability. Model discriminative performance was presented with the area under Receiver operating classification curve (AuROC). Model calibration was performed using Hosmer-Lemeshow goodness-of-fit statistical analysis. A bootstrap resampling procedure with 200 replications was used to internally validate the developed model. Posthoc power analysis using G*Power (version 3.1, Heinrich Heine University, Düsseldorf, Germany) was performed.

For practicality, the developed model was presented by the predictive scoring system. First, the weighted score was derived from each predictor's regression coefficient (β). Then, the total score was then categorized into three groups (low, moderate, and high risk) to assist physicians in decision-making for performing prophylactic contralateral hip procedures.

RESULTS

A total number of 30 CP patients who initially developed a unilateral hip dislocation were included in this study. The patients' demographic data at the index visit are presented in Table 1. Of 30 patients, contralateral hip dislocation happened in seven (23.3%) patients.

A statistically significant difference was noted between the demographics of the dislocated group and the non-dislocated group at the index visit. The body weight and height are significantly lower in the dislocated group ($p = 0.050$ and p.= 0.006, respectively). However, the mean age is not significantly different between the two groups ($p = 0.213$). There were no significantly different proportion of topographical classification ($p = 0.386$) and GMFCS ($p = 0.936$) between two groups. The proportion of patients who underwent VDRO between the two groups is not significantly different ($p = 0.64$).

Preoperative parameters that indicate hip dysplasia of the contralateral side, which are the RMI, AI, and CEA, are significantly different between the two groups (Table 1). RMI of the contralateral side is higher in the dislocated group (30.2% ± 7.1%, range 15.4–36.3% vs. 23.5 ± 7.8%, range 13.0–38.0%, $p = 0.049$), and the AI is also higher ($p = 0.019$). The CEA of the contralateral hip is lower in the dislocated group ($p = 0.030$). No statistical difference was noted regarding the RMI ($p = 0.893$), AI ($p = 0.603$), and CEA ($p = 0.673$) of the dislocated side. The NSA is not different between the two groups for both the dislocated side ($p = 0.337$) and the contralateral side ($p = 0.885$). The preoperative pelvic obliquity is significantly lower ($p = 0.038$) in the group in which the contralateral hip is eventually dislocated.

VDRO was performed in 21 patients (70.0%). In these patients, adductor tenotomy was also performed on the contralateral side. Out of 21 patients, their contralateral hip eventually dislocated in four (19.0%). Contralateral hip dislocation in patients who received VDRO is slightly lower than in patients who did not (19.0% vs. 33.3%, $p = 0.640$). The remaining 17 hips which the contralateral side did not dislocate have their RMI slightly decrease from 20.76 ± 6.14% to 18.47 ± 7.58%. However, it is not statistically significant.

The dislocated group's mean pelvic obliquity at the last follow-up visit was −1.86° ± 6.203° compared to 8.00° ± 9.648° in the non-dislocated group. The difference is statistically significant ($p = 0.017$). The degree of pelvic obliquity correction ($p = 0.259$) and the presence of pelvic obliquity reversal ($p = 0.345$) are not significantly different between the two groups.

The mean follow-up time is 36.92 ± 23.82 months (range, 12.12–103.49 months). The mean time after the index visit until the contralateral hip dislocate is 16.95 ± 8.13 months (range, 7.82–29.44 months). Out of 30 patients, 14 patients (46.7%) were followed until maturity. Three of these patients (21.4%) developed contralateral hip dislocation. When only complete follow-up patients were analyzed, parameters that were statistically different were the RMI (34.0 ± 3.6% vs. 20.6 ± 6.4%, $p = 0.005$) and AI (24.0° ± 9.1° vs. 16.0° ± 4.2°, $p = 0.041$) of the contralateral dislocated group and not dislocated group respectively.

During the follow-up period, there were five patients whose GMFCS changed. Two out of 7 patients (28.5%) who initially presented with GMFCS V improved to GMFCS IV. Three out of 13 (23.1%) patients initially presented with

Table 1. Demographic data of cerebral palsy patients categorized by the presence of contralateral hip dislocation

Таблица 1. Демографические данные пациентов с центральным параличом, распределенные по статусу наличия вывиха контралатерального бедра

Demographic data	Contralateral hip dislocation (*n* = 7, 23.3%)		No contralateral hip dislocation (*n* = 23, 76.7%)		*p*-value
	Mean	±SD	Mean	±SD	
Clinical characteristics					
Age, months	76.4	63.4	105.7	50.2	0.213
Sex, *n*, %					
Male	4	57.1	12	52.2	1.000
Female	3	42.9	11	47.8	
Body weight, kg	13.9	3.6	23.4	11.7	0.050
Body height, cm	109.0	1.4	125.4	18.5	0.006
Topographic classification, *n*, %					
Spastic Diplegia	2	28.6	11	47.8	0.386
Spastic Quadriplegia	5	71.4	10	43.5	
Spastic hemiplegia	0	0.0	2	8.7	
GMFCS classification, *n*, %					
GMFCS II	0	0.0	1	4.4	0.936
GMFCS III	2	28.6	7	30.4	
GMFCS IV	3	42.9	10	43.5	
GMFCS V	2	28.6	5	21.7	
Received Femoral VDRO[2]	4	57.1	17	73.9	0.640
Radiographic parameters					
Unstable hip					
RMI, %	63.4	26.5	64.8	22.0	0.893
AI (°)	31.3	8.0	29.7	6.7	0.603
CEA[5] (°)	–17.1	38.0	–12.4	21.7	0.673
NSA[6] (°)	157.7	5.4	154.4	8.4	0.337
Contralateral hip					
RMI, %	30.2	7.1	23.5	7.8	0.049
AI (°)	27.8	8.6	20.3	6.5	0.019
CEA (°)	9.7	11.8	20.5	10.7	0.030
NSA (°)	155.9	8.3	155.4	8.0	0.885
Pelvic obliquity (°)	1.7	3.5	6.6	5.5	0.038
Presence of pelvic obliquity reversal, *n*, %	3	42.9	5	21.7	0.345

Note. GMFCS, Gross Motor Function Classification System; VDRO, Varus Derotation Osteotomy; RMI, Reimer's Migration Index; AI, Acetabular Index; CEA, Lateral Center Edge Angle of Wiberg; NSA, Femoral Neck Shaft Angle.

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Table 2. Univariable and full model multivariable logistic regression for predicting contralateral hip dislocation in cerebral palsy children

Таблица 2. Однофакторная и полная многофакторная модели логистической регрессии для прогнозирования вывиха контралатерального бедра у детей с церебральным параличом

Characteristics	Univariable analysis			Multivariable analysis			
	uOR	95% CI	*p*-value	mOR	95% CI		*p*-value
Age <9 years	5.66	0.68–63.33	0.105	22.55	0.76	665.37	0.071
Non-ambulators*	1.33	0.21–8.49	0.761	0.51	0.02	10.88	0.669
RMI > 25°	11.25	1.15–110.46	0.038	36.66	1.13	1185.50	0.042
AI > 25°	2.13	0.36–12.38	0.402	0.49	0.03	7.98	0.614
CEA < 25°	4.62	0.48–44.76	0.187	0.46	0.02	13.71	0.657

*Gross Motor Function Classification System (GMFCS) IV & V.
Note. RMI, Reimer's Migration Index; AI, Acetabular Index; CEA, Lateral Center Edge Angle of Wiberg

*IV и V уровни по системе классификации больших моторных функций (GMFCS).
Примечание. мОШ — медиана отношения шансов; RMI — миграционный индекс Реймерса; АИ — ацетабулярный индекс; CEA — латеральный центрально-краевой угол Виберга.

Table 3. Multivariable logistic regression for predicting contralateral hip dislocation in cerebral palsy children after backward elimination of preselected predictors with transformed coefficients and assigned score

Таблица 3. Многофакторный анализ с помощью метода логистической регрессии для прогнозирования вывиха контралатерального бедра у детей с центральным параличом после обратного исключения предварительно выбранных прогнозирующих факторов с трансформированными коэффициентами и присвоенным баллом

Characteristics	Multivariable analysis			Score	
	β	95% CI	*p*-value	Transformed β	Assigned score
Age <9 years	2.27	−0.22–4.75	0.074	1.00	1
RMI >25°	2.73	0.29–5.17	0.029	1.20	1

Note. RMI, Reimer's Migration Index

Примечание. RMI — миграционный индекс Реймерса.

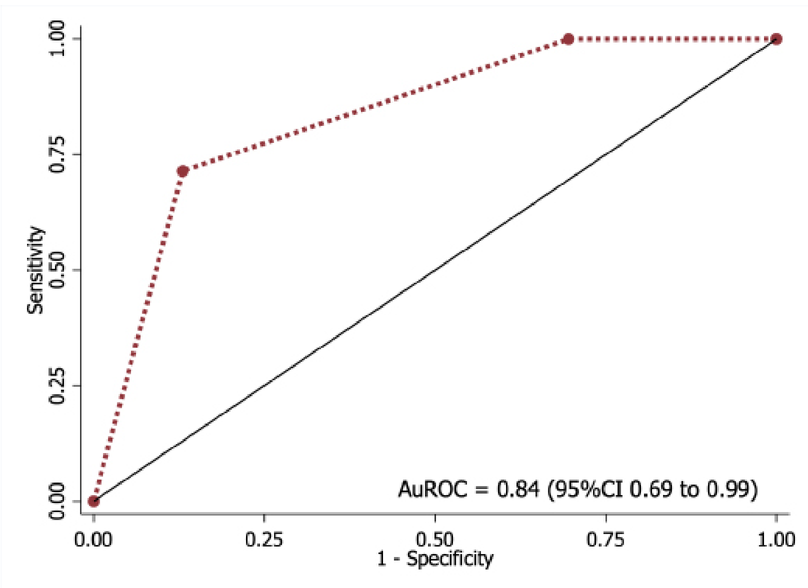

Fig. 1. ROC curve of the final model
Рис. 1. ROC-кривая окончательной модели

Таблица 4. Распределение вывиха контралатерального бедра по категориям умеренного и высокого риска

Table 4. Distribution of contralateral hip dislocation into moderate and high risk categories

Risk categories	Score	Dislocation, *n* (%)		Stable, n (%)		Sensitivity	95% CI	Specificity	95% CI
Low risk	0	0		7 (30.4)		100.0	59.0–100.0	0.0	0.0–0.2
Moderate risk	1	2 (28.6)		13 (56.5)		100.0	59.0–100.0	30.4	13.2–52.9
High risk	2	5	71.4	3	13.0	71.4	29.0–96.3	87.0	66.4–97.2
Total score (Mean ± SE)		1.7	0.2	0.8	0.1			p-value	0.003

GMFS IV improved to GMFCS III. No patients in this study have deterioration of their GMFCS.

In univariable logistic regression, RMI more than 25% was identified as statistically significant predictor (mOR 22.55, 95% CI 1.15–110.46, $p = 0.038$) , and it still shows significance in multivariable logistic regression analysis (mOR 36.66, 95% CI 1.13–1185.50, $p = 0.042$. The other significant predictor identified in multivariable logistic regression analysis is the age <9 years old (mOR = 22.55, 95% CI 0.76–665.37, $p = 0.071$) (Table 2).

Step-wise backward elimination of all selected factors was performed, and the significant factors from multivariable logistic regression were then included in a final model. The coefficients were transformed, and a proper score was assigned for each factor (Table 3). The Receiver operating characteristic (ROC) curve shows the AuROC of 0.84 (95% CI 0.69–0.99) (Figure 1). Internal validation reveals a shrinkage factor of 0.80. Calibration with Hosmer – Lemeshow test yield *p*-value of 0.755, indicating good calibration. Posthoc power analysis was performed by given values as follows: the probability of rejecting the null hypothesis (H_0) in high-risk patients — 0.36, prespecified α 0.05, sample size — 30, pseudo $R_2 = 0.29$, effect size (determined by the probability of events). As a result, the calculated power analysis revealed the final model power of 0.62.

According to the risk of contralateral hip displacement, the developed score was categorized into a low (score 0), moderate (score 1), and high-risk group (score 2). There was no contralateral hip displacement in patients who had a score of 0 (0/7 patients). Two out of 15 patients (28.6%) who had a score of 1 developed contralateral hip dislocation. For the patients with a score of 2, 5 out of 8 (71.4%) developed contralateral hip dislocation (Table 4).

DISCUSSION

Our study shows a rate of contralateral hip dislocation of 23% (7/30 hips). The rate of contralateral hip dislocation in other series varied from 4% to 75% [4, 6, 7]. The high variation observed is most likely from the heterogeneity of patients' characteristics and the varying degree of RMI's cut point of dislocation. The different surgical techniques, including soft tissue release alone, VDRO, acetabular osteotomy, or combined procedure, may also contribute to this variety.

The main finding of this study is that the risks for contralateral hip dislocation are significantly related to the inherent stability and dysplastic of that side itself. This is supported by the significant difference of the contralateral side's RMI, AI, and CEA between the dislocated group and the non-dislocated group. The explanation is that all contralateral hips will have some degree of progression eventually. However, the hip with more coverage at the starting point will be less likely to progress to the cut point of dislocation. Noonan et al. [7] also found that contralateral hips that required surgery had an initial RMI of 32%, in contrast to 17% in those who did not ($p = 0.001$). L.C. Abdo et al. [4] found that, in patients with unilateral hip dislocation, of nine patients for whom the contralateral hip RMI is <30% and AI is <25° at the immediate post-operative period, only one evolved to subluxation.

The severity of motor impairment is related to the progression of the hip in CP. In the systematic review by B. Pruszczynski et al. [19], there is a linear relationship between increasing GMFCS and the risk of hip displacement. However, in our study, we failed to demonstrate this relationship. Even though the patients whose contralateral hip eventually dislocated have a slightly higher proportion of non-ambulators (71.4% vs. 66%, $p > 0.05$), the difference is not statistically significant. The reason may be due to a low number of ambulators in this cohort, which might not be enough to provide a statistical difference.

Parameters related to pelvic balance are also of interest as predicting factors. F. Canavese et al. [12] found that reversal of pelvic obliquity after the operation correlates with subsequent contralateral hip displacement. Hagglund et al. found a strong association between the high side of PO and the side of the highest RMI. We believed that the surgery on the dislocated hip might change the hip abductor function and biomechanics, leading to a reversal of pelvic obliquity, which places the contralateral hip in relative adduction and leads to progression. This is supported by our findings that the PO in the contralateral dislocated group is lower pre-operatively and changes to a negative value during the follow-up period. Although additionally, the presence of pelvic obliquity reversal in the dislocated group is higher (43% vs. 21%), it is not of statistical significance. The number of patients in this cohort may be too few to prove a statistically significant difference.

The effect of surgery on the unilateral dislocated hip was believed to have a negative impact on the contralateral hip in the past [6]. However, more recent studies, including our research, proved that the surgery alone is not a prognostic factor for contralateral hip dislocation. J.E. Gordon et al. [20] found that of 48 patients with unilateral hip dislocation who underwent VDRO, only 1 case (4.2%) developed subluxation of the contralateral hip. However, a higher proportion of ambulatory patients (41.7%) in their study might explain the lower rate of contralateral hip dislocation.

Multivariable logistic regression identifies two significant predicting factors for contralateral hip dislocation: age <9 years and initial RMI >25%. Younger age at presentation of unilateral hip dislocation has been linked to the progression of the contralateral hip in a study by C. Carr et al. [6]. In their study, femoral head coverage deteriorated more significantly in patients younger than nine years old (12.5% vs. 0.2%, $p < 0.05$). Younger patients have more remaining growth, and as the bone lengthened while the muscle remains short and spastic, this would lead to progressive subluxation of the contralateral hip. Even though all patients received bilateral adductors release in our cohort either separately or as a part of a single event multilevel surgery, this might not entirely prevent the contralateral hip from progressing.

In recent years, there has been increasing interest in bilateral hip surgery for CP patients, primarily for a bilaterally dislocated hip. However, the decision to perform concomitant surgery of the contralateral hip in patients with unilateral hip dislocation is still controversial. A decision analysis performed by M.S. Park et al. [21] favors concurrent prophylaxis of the contralateral hip when the rate of the contralateral hip progression is ⩾27%.

Bilateral hip reconstruction in patients with bilateral hip dislocation has provided satisfactory pain relief, improved hip range of motion, and improved radiologic parameters [22]. Furthermore, a Same-day bilateral hip surgery provided a lower rate of major complications, unplanned readmissions, and reoperations than a staged surgery [23].Concurrent prophylactic VDRO was performed in 80 hips in a study by K.H. Sung et al. [24]. The result shows no progression of the stable contralateral hip after surgery. However, if the contralateral hip is displaced at the time of surgery, there is an increased risk for post-operative subluxation. N. Kamisan et al. [25] retrospectively compared bilateral and unilateral hip reconstruction in CP patients with unilateral hip subluxation. The result shows that bilateral surgery results in a lower mean post-operative PO (5.6 vs. 2.1, $p = 0.001$) and a higher proportion of functional improvement,

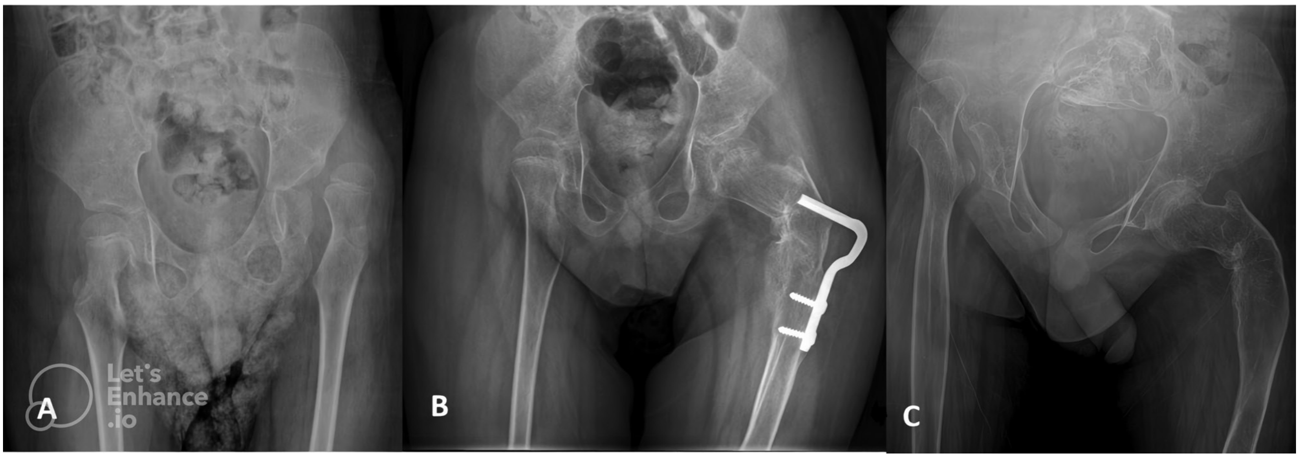

Fig. 2. X-rays of patient 6 year-old with cerebral palsy: *a* — with a unilateral left hip dislocation; *b* — the right hip's Reimer's Migration Index is 18%. Varus derotation osteotomy was performed on the left hip; *c* — two years after the operation, the right hip is dislocated
Рис. 2. Рентгенограммы пациента 6 лет с церебральным параличом: *a* — односторонний вывих левого бедра. Миграционный индекс Реймерса правого бедра составляет 18 %; *b* — деротационно-варизирующую остеотомию проводили на левом бедре; *c* — через 2 года после операции развился вывих правого бедра

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Fig. 3. X-rays of patient 3 year-old with cerebral palsy: *a* — with right hip dislocation. Left hip's Reimer's Migration Index is 36%; *b* — varus derotation osteotomy was planned, but the parent denied surgery; *c* — both hips eventually progressed

Рис. 3. Рентгенограммы пациента 6 лет с церебральным параличом: *a* — вывих правого бедра. Миграционный индекс Реймерса левого бедра составляет 36 %; *b* — была запланирована деротационно-варизирующая остеотомия, но родители ребенка отказались; *c* — последующее прогрессирование вывиха обоих бедер

including sitting, standing, and walking. PO is believed to be correlated with pain and postural balance [26], but the other patient-reported outcomes would help to confirm its clinical significance.

These studies show that bilateral hip surgery for unilateral hip dislocation looks promising. However, many patients will still not have progression of the contralateral hip, and concomitant surgery might be considered an overtreatment. Many reports on unilateral hip surgery also show a good outcome [7, 27–31]. Nevertheless, our series reported a mean post-operative pelvic obliquity of 3.9°. This value is within 5°, which is considered the threshold for poor outcome [25, 32], indicating that unilateral surgery might be sufficient for some selected patients.

Some limitations are presented in our study. First, the number of participants is relatively low. This is due to the healthcare referral system of Thailand. Many patients are referred to us, a university-affiliated hospital, for surgery. Some opt to follow up at their local hospital post-operatively, and we need to exclude them from the study.

Second, the follow-up time of patients in this study is not uniform, and the mean follow-up time is about three years. On the other hand, the time to contralateral hip dislocation is reported as around 2–5 years [11, 12, 15]. Therefore, the dislocation rate might be underestimated. However, roughly half of the participants are followed to skeletal maturity, and the subgroup analysis of these patients revealed a similar rate of contralateral dislocation.

Third, although the prediction model developed has an excellent AuROC, the posthoc power analysis of 0.62 means that the model might need more participants. External validation of the model and a prospective study with more patients are still needed to confirm these findings. However, our developed score can still be used to advise patients regarding the risk for contralateral hip dislocation.

For low-risk patients with a score of 0 (age > 9 years old and RMI <25%), the contralateral hip is less likely to progress. For patients who have a score of 1. They should be advised regarding the moderate risk of contralateral hip dislocation. Risks and benefits of concurrent prophylaxis VDRO should be discussed, and shared decision-making is encouraged. Post-operative regular clinical exams and radiographs are necessary to detect the contralateral hip progression (Figure 2). Lastly, patients younger than 9 with an RMI >25% should be advised regarding a high risk of contralateral hip dislocation, and bilateral VDRO might be considered (Figure 3).

CONCLUSIONS

Differences of preoperative RMI, AI, CEA, and PO suggest that these factors may significantly predict contralateral hip dislocation. However, using multivariable logistic regression, only RMI >25% and age <9 years old were identified as predicting factors. The proposed scoring system might help guide the surgeon's decision to perform contralateral prophylactic surgery.

ADDITIONAL INFORMATION

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Author contribution. Thereby, all authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work. Pasin Tangadulrat — study design, manuscript drafting, data acquisition, and interpretation;

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Ethical approval. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.The ethics committee for our hospital approved the study.

Competing interests. The authors declare that they have no competing interests.

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