OPEN Research Article

From Hip Screening to Hip Surveillance: Transforming Care for Patients With Cerebral Palsy: An Analysis of a Single Institution

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ABSTRACT

Introduction: Surveillance programs aimed at monitoring hip displacement in patients with cerebral palsy have been demonstrated to decrease the incidence of hip dislocations and properly time surgical intervention, ultimately improving patient outcomes. The objective of this study was to determine whether the implementation of a hip screening to surveillance program at a tertiary academic teaching hospital in 2017 increased the frequency of radiographic evaluations and changed the timing of surgical intervention.

Methods: A total of 592 patients with cerebral palsy were identified, and 468 of these patients had initial radiograph date data available. In this analysis, 246 patients with initial radiograph dates after 2012 were included. The study population was divided into two groups based on the initial radiograph date, 2012 to 2016 versus 2017 to 2022. One hundred sixty patients (65%) were in the 2012 to 2016 group, and 86 (35%) were in the 2017 to 2022 group. Statistical analysis was conducted using various techniques, such as two-sample Student *t*-test, Mann-Whitney *U* test, chi square/Fisher exact test, and multivariable linear regression analysis.

Results: The average number of radiographs per year in the 2017 to 2022 group was 0.11 (95% CI: 0.02, 0.20, $P = 0.017$) higher than the 2012 to 2016 group. After adjusting for confounders using multivariable linear regression analysis, this difference was even larger (difference 0.16, 95% CI: 0.06, 0.25, $P = 0.001$). The surgical intervention rate was significantly lower in the 2017 to 2022 group compared with the 2012 to 2016 group (12.9% versus 40.6%, $P < 0.001$).

Discussion: The results of this study suggest that the implementation of a hip screening to surveillance program results in more frequent radiographic evaluations and possibly a reduced need for surgical intervention from 2017 to 2022. In the 2012 to 2016 group, more

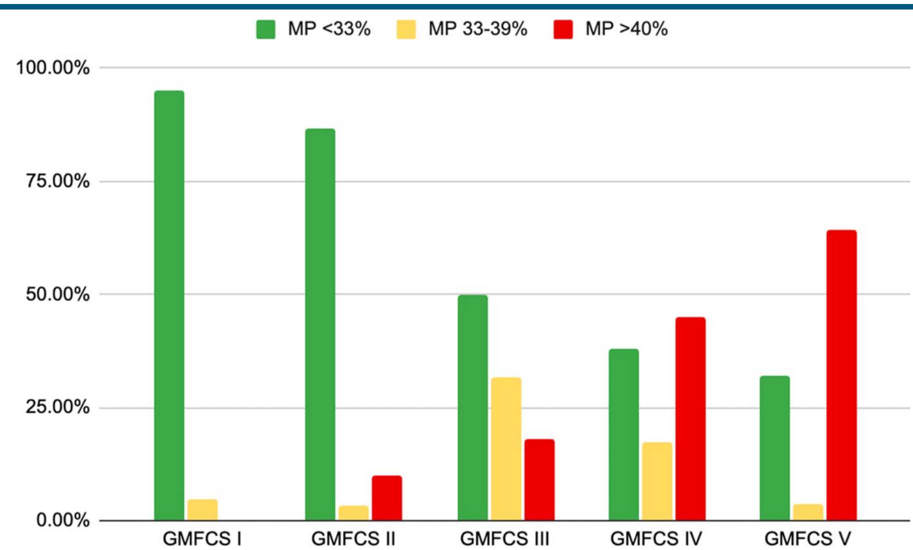
surgical interventions were performed likely because of the lack of any hip surveillance or screening program in place.

Hip displacement is defined as the displacement of the femoral head laterally out of the acetabulum[1] and is a prevalent issue among pediatric patients with cerebral palsy (CP).[2] Children with CP are at increased risk of hip displacement, which can result in dislocation if not detected early.[3] The progression of hip displacement may lead to the feared sequelae of pain, fixed deformity, and decreased function and quality of life.[4,5] Displacement can be assessed by calculating the migration percentage (MP) from radiographic images.[6,7] With proper positioning, the MP produces a reliable and reproducible measure of lateral hip displacement and is useful in hip surveillance.[2,8] A MP of >30% generally warrants orthopaedic referral.[9] Increased risk of hip displacement has been correlated with impaired gross motor function, evidenced by a higher level based on the Gross Motor Function Classification System (GMFCS).[2,6,10] The GMFCS allows medical providers to objectively assess prognosis and determine appropriate treatment goals for patients with CP, with a higher level indicating an increased severity of motor disability.[9]

Hip surveillance programs monitor patients with CP to detect hip displacement early to manage it[11] and prevent long-term sequelae (Figure 1).[12,13] These programs involve regular radiographic and clinical assessment based on the child's MP and GMFCS level.[10] Surveillance programs have been demonstrated to decrease the incidence of hip dislocations[14] and properly time surgical intervention, ultimately improving patient outcomes.[6] Although hip surveillance has been successfully implemented in Australia, British Columbia, and parts of Europe, it has not been adopted universally in the United States for children with CP.[6] Despite overall consensus that a US-based hip surveillance program would improve outcomes for patients with CP,[15] no nationwide program has been created thus far. There is also limited knowledge on how to best implement a national hip surveillance program and whether a US-based hip surveillance program will yield similar results to other countries.

Before the introduction of clear hip surveillance guidelines at our institution, there was no standardization regarding when patients with CP were referred to orthopaedic surgery and how often radiographic evaluation was performed. While some patients were referred before hip pathology manifested, others were only referred after endorsing symptoms related to hip displacement. Furthermore, radiographic hip monitoring was based on provider preference/training as opposed

Figure 1



Graph showing the proportion of children (%) with a migration percentage (MP) of <33% (*green*), 33 to 39% (*yellow*), and ≥40% (*red*) in relation to the Gross Motor Function Classification System (GMFCS) level in the total population of children with cerebral palsy (CP).[13,16]

to a specific protocol. In 2017, hip surveillance guidelines were established and distributed across our institution to address these inconsistencies.

The hip surveillance guidelines distributed at our institution consisted of a comprehensive manual based on Australia's nationwide hip surveillance program. This guide instructed providers to begin screening patients with CP for hip pathology with radiographs beginning at the age of 2 years and occurring every 6 months afterward if hip subluxation was found. In addition to explaining radiographic measurements related to hip surveillance, they were then recommended to refer patients for orthopaedic assessment when MP progressed to greater than 30%, when there was pain related to the hip, or when there were any other musculoskeletal conditions or concerns identified. On evaluation, it was considered necessary to increase the frequency of hip surveillance in the following situations: when there was a decline in function, such as changes in walking, decreased ability to sit or stand, or reduced tolerance for these activities; when there were indications of scoliosis, pelvic obliquity, or noticeable differences in leg length; when there was a deterioration in musculoskeletal measures related to the hip, such as changes in muscle tone (including increased spasticity), reduced range of motion, shortened muscles, or increased asymmetry in the range of motion; when there were increased difficulties with perineal care and hygiene; and when there was onset or worsening of hip pain.[16] Children who were identified to be candidates for continued monitoring were scheduled for pelvic and/or hip radiographs every 6 months to continue to assess changes in MP and displacement. In addition, they would be scheduled for follow-up with an interdisciplinary team to review radiograph results and recommend both surgical and nonsurgical interventions. Given the novelty of these guidelines at our institution and the lack of a national CP database, a true hip surveillance program was difficult to implement immediately. Instead, the guidelines introduced a hip screening program with the ultimate goal of progressing to true hip surveillance in the near future.

The objective of this study was to determine whether the implementation of a hip screening program at our US-based institution in 2017 increased the frequency of radiographic evaluations and changed the timing of surgical intervention. We hypothesize that a hip screening program at our tertiary academic institution will follow global trends and result in more frequent radiographic evaluations and earlier identification of patients with CP and reduce the need for surgical interventions in this population. Furthermore, we hypothesize that a successful hip screening program will provide the foundation to establish a more robust hip surveillance program.

Methods

Study Design

This retrospective chart review aimed to assess the effect of a hip screening program on pediatric patients with CP treated at a tertiary academic teaching hospital. The study design involved a comparative analysis of two patient groups: the preimplementation group (2012 to 2016) and the postimplementation group (2017 to 2022). Institutional review board approval was obtained from the hospital system.

Study Population

This study included pediatric patients diagnosed with CP who received treatment within the orthopaedic surgery department of the hospital between 2012 and 2022. Patients with a diagnosis of CP before or during the study period with initial hip or pelvis radiograph data available were included in this study. A total of 592 patients were initially identified, of which 468 had initial radiograph dates documented. For the purpose of this study, patients with hip or pelvic radiographs dated before 2012 were excluded to ensure the preimplementation and postimplementation groups were comparable. Therefore, a subset of 246 patients with initial radiograph dates after 2012 was included, with 160 patients in the preimplementation group and 86 patients in the postimplementation group.

Intervention: Hip Screening Program

The hip screening program aimed to optimize patient outcomes by implementing a comprehensive approach for the management of hip conditions in pediatric patients with CP. The program mirrored established programs already implemented in Australia, British Columbia, and parts of Europe and followed the protocols established by the American Academy for Cerebral Palsy and Developmental Medicine. In Australia, the hip surveillance program is evidence-based, provides practical guidance for preventing hip dislocation in patients with CP, and has been endorsed by the Australasian Academy of Cerebral Palsy and Developmental Medicine.[14] The program includes several interventions, including regular radiographic evaluations, follow-up appointments, and timely interventions such as reconstructive surgeries and nonsurgical treatments such as

Table 1. The Baseline Demographic and Clinical Characteristics of the Study Population

Characteristics	Levels	Overall (N = 246)	2012 to 2016 (N = 160)	2017 to 2022 (N = 86)	*P**
Age at initial radiograph (years)	Mean (SD)	7.4 (3.6)	6.4 (3.5)	9.1 (2.9)	**<0.001**
Sex, n (%)	Male	140 (56.9)	88 (55.0)	52 (60.5)	0.409
	Female	106 (43.1)	72 (45.0)	34 (39.5)	–
Race, n (%)	Black/African American	97 (40.4)	64 (41.0)	33 (39.3)	0.812
	White	69 (28.7)	43 (27.6)	26 (31.0)	–
	Asian	8 (3.3)	4 (2.6)	4 (4.8)	–
	Hispanic/Latino	1 (0.4)	1 (0.6)	0 (0.0)	–
	American Indian/Alaska Native	1 (0.4)	1 (0.6)	0 (0.0)	–
	Other race	64 (26.7)	43 (27.6)	21 (25.0)	–
Ethnicity, n (%)	Not Hispanic/Latino/Spanish	177 (75.3)	112 (74.7)	65 (76.5)	0.758
	Hispanic/Latino/Spanish	58 (24.7)	38 (25.3)	20 (23.5)	–
Type of CP, n (%)	Diplegic	64 (30.0)	40 (30.5)	24 (29.3)	0.310
	Triplegic	1 (0.5)	1 (0.8)	0 (0.0)	–
	Hemiplegic	35 (16.4)	17 (13.0)	18 (22.0)	–
	Quadriplegic	113 (53.1)	73 (55.7)	40 (48.8)	–
GMFCS data, n (%)	Not available	103 (41.9)	83 (51.9)	20 (23.3)	**<0.001**
	Available	143 (58.1)	77 (48.1)	66 (76.7)	–
GMFCS level breakdown, n (%)	Not available	103 (41.9)	83 (51.9)	20 (23.3)	**0.001**
	I	9 (3.7)	3 (1.9)	6 (7.0)	–
	II	32 (13.0)	17 (10.6)	15 (17.4)	–
	III	23 (9.3)	12 (7.5)	11 (12.8)	–
	IV	40 (16.3)	21 (13.1)	19 (22.1)	–
	V	39 (15.9)	24 (15.0)	15 (17.4)	–

**P* values were obtained from two-sample Student *t*-test for continuous data and from chi square/Fisher exact test for binary and categorical data.
Significant *P* values are in bold.

botox injections. The program was introduced to address the lack of standardized follow-up protocols for patients with CP and to facilitate early detection and intervention. As previously described, our institution's hip surveillance guidelines consisted of AP hip/pelvis radiographs beginning at the age of 2 years with repeat imaging completed every 6 months. Surgical intervention was considered with a MP greater than or equal to 30%.

Data Collection and Analysis

A retrospective review of patient charts was conducted to collect relevant data. Demographic and clinical characteristics, including age, sex, race, ethnicity, type of CP, and GMFCS levels, were extracted from the medical records. The primary outcome measures included the frequency of obtained radiographs and rate of surgical interventions.

Statistical analyses were conducted using R statistical software (version 4.0.03). Two-sample Student *t*-test, Mann-Whitney *U* test, chi square/Fisher exact test, and multivariable linear regression analysis were used to evaluate the differences between the preimplementation and postimplementation groups. All statistical tests were two-sided, and a significance level of 0.05 was used. The mean, standard deviation, median, interquartile range, and confidence intervals were calculated as appropriate.

Ethical Considerations

This study was conducted in accordance with ethical principles and received approval from the Institutional Review Board. Confidentiality and privacy of patient

Table 2. Mean and Median Average Number of Radiographs per Year

Number of Radiographs per year	2012 to 2016	2017 to 2022	Difference (95% CI)	*P**
Median (IQR)	0.20 (0, 0.6)	0.33 (0.17, 0.67)	0.13	**0.05**
Mean (SD)	0.36 (0.46)	0.47 (0.51)	0.11 (0.02, 0.20)	**0.017**

IQR = interquartile range, SD = standard deviation, CI = confidence interval
**P* values were obtained from Mann-Whitney *U* test (median) and two-sample Student *t*-test (mean).
Significant *P* values are in bold.

data were strictly maintained throughout this study, with all data deidentified and securely stored.

Results

Demographic and Clinical Characteristics

A total of 246 pediatric patients with CP were included in this study, with 160 patients in the 2012 to 2016 group and 86 patients in the 2017 to 2022 group. The baseline demographic and clinical characteristics of the study population are summarized in Table 1.

The age at the initial radiograph was significantly higher in the 2017 to 2022 group compared with the 2012 to 2016 group (9.1 years versus 6.4 years, $P < 0.001$). Furthermore, the availability of GMFCS data was significantly higher in the 2017 to 2022 group (76.7% versus 48.1%, $P < 0.001$). No notable differences were observed between the two groups in terms of sex, race, ethnicity, type of CP, or other demographic characteristics.

Average Number of Radiographs

The average number of radiographs obtained per year increased markedly in the 2017 to 2022 group compared with the 2012 to 2016 group. The average number of radiographs obtained per year in the 2017 to 2022 group was 0.11 (95% CI: 0.02, 0.20, $P = 0.017$) higher than the 2012 to 2016 group. After adjusting for age at the initial radiograph, sex, race, ethnicity, and type of CP using multivariable linear regression analysis, the difference became even more significant (difference: 0.16, 95% CI: 0.06, 0.25, $P = 0.001$). The median number of radiographs obtained per year also showed a similar pattern, with a higher value in the 2017 to 2022 group compared with the 2012 to 2016 group (0.33 versus 0.20, $P = 0.05$) (Figure 2, Table 2).

Surgery Rate

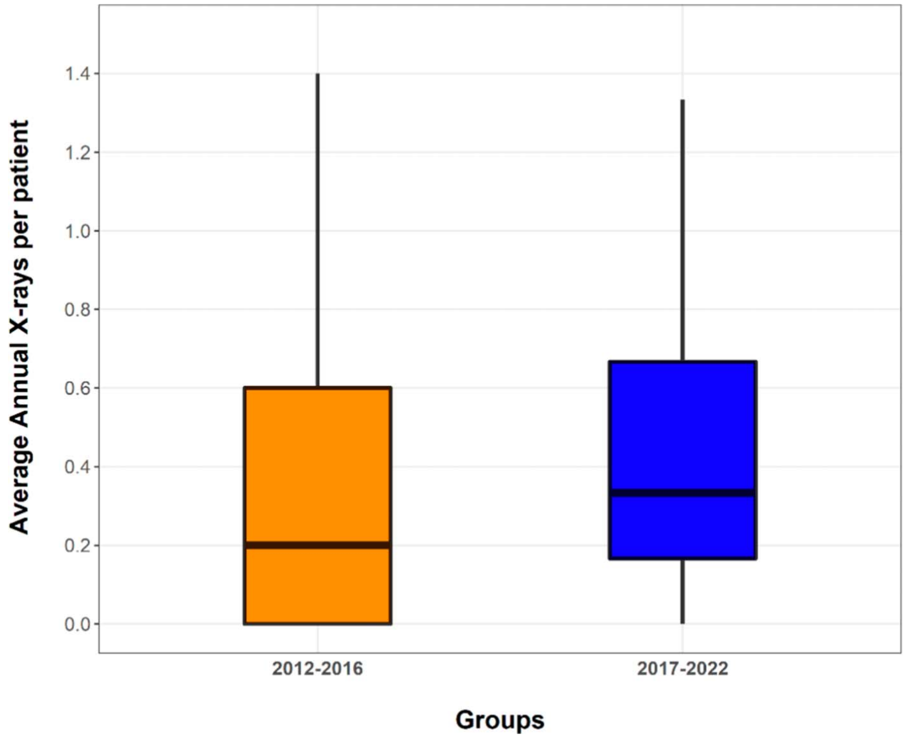
The intervention (surgery) rate was significantly lower in the 2017 to 2022 cohort compared with the 2012 to 2016 cohort (12.9% versus 40.6%, $P < 0.001$). When examining the type of intervention, the rate of reconstructive surgeries in the 2017 to 2022 group was significantly lower than in the 2012 to 2016 group (10.6% versus 23.8%, $P < 0.001$). No significant differences were observed in the mean age at intervention between the two groups (8.9 years in 2017 to 2022 versus 8.4 years in 2012 to 2016, $P = 0.676$) (Table 3).

Discussion

The findings of this study indicate that the implementation of a hip screening program at our academic institution affected both the frequency of radiographic evaluations and the timing of surgical interventions in patients with CP. Based on our results, there is a statistically significant increase in the average number of radiographs per year from 2017 to 2022, when the hip screening program was founded, compared with previously from 2012 to 2016. Age at initial radiograph is also markedly higher in the 2017 to 2022 cohort compared with the 2012 to 2016 cohort. Rate of surgical intervention is markedly lower in the 2017 to 2022 group compared with the 2012 to 2016 group; however, the age at surgical intervention shows no notable difference between the two cohorts. The results confirm our initial hypothesis that a hip screening program at our institution would result in more frequent radiographic evaluations and a reduced rate of surgical interventions for patients with CP because we are more closely monitoring the hip pathology before surgical indication.

The fact that age at initial radiograph in this study averaged 9.1 years after starting the screening program, compared with the Australian guideline–recommended age of 2 years, is curious because it was expected that children with CP would present earlier with this program in place. This could suggest that we more aptly initiated a hip screening program rather than true surveillance because children were radiographed after they were referred for treatment in their current state of disease progression instead of earlier as recommended for true surveillance. The markedly older age at the

Figure 2



Graph showing average annual radiographs per patient vs presurveillance and postsurveillance program groups.

initial radiograph in the postimplementation period also suggests that the screening program facilitated increased vigilance in monitoring hip health in this specific population. Previous studies conducted in Europe and Australia with well-established hip surveillance programs have yielded different results, with their programs finding hip displacement in patients as young as 2 years.[17-19] The increased availability of GMFCS data that come from hip surveillance programs further supports the notion that these programs improve the comprehensive assessment of patients, enabling a more informed decision-making process when surgical interventions are considered. Unfortunately, the hip screening program at our institution did not yield similar results to the programs in Europe and Australia, likely from confounders such as timing of referrals from outside providers.

The observed statistically significant increase in the average number of radiographs per year highlights the success of the program in promoting a proactive approach to monitoring hip health in patients with CP. Although our results do not show a clinically significant increase, this could also be from confounders that we did not account for. Our results were based on the number of radiographs that were actually completed; however, these do not account for patients who were lost to follow-

Table 3. Rate of Surgery

Characteristics	Levels	2012 to 2016 (N = 160)	2017 to 2022 (N = 86)	*P**
Intervention rate, n (%)		65 (40.6)	11 (12.9)	<**0.001**
Intervention type, n (%)	None	95 (59.4)	74 (87.1)	<**0.001**
	Preventive	26 (16.2)	2 (2.4)	
	Salvage	1 (0.6)	0 (0.0)	
	Reconstructive	38 (23.8)	9 (10.6)	
Age at intervention (years)	Mean (SD)	8.4 (3.8)	8.9 (1.9)	0.676

**P* values were obtained using chi square/Fisher exact test.
Significant *P* values are in bold.

up or did not show for radiographic evaluation. Proactive monitoring of hip health of patients with CP is important in the prevention of more severe sequelae, such as hip dislocation; loss of ability to perform ADLs; and functional neuromuscular, respiratory, and GI decline.[2,20,21] Several studies have looked into when hip surveillance should begin for patients with CP given the high rate of dislocation. For example, Scrutton et al (2001) recommended that patients with bilateral CP should begin screening at the age of around 30 months, correcting for gestational age after comparing this population with a control group without CP.[17] Most programs follow the guidelines set by the Australasian Academy of Cerebral Palsy and Developmental Medicine[14,16] and recommend that surveillance begin shortly after CP diagnosis, around the age of 2 years. More frequent radiograph surveillance likely contributes to prompt identification of progressive hip abnormalities, enabling close monitoring of disease progression. Early identification also allows for clinicians to practice preventive medicine, allowing for decreased incidence of hip dislocation in patients with CP who participate in hip surveillance programs.[17,22] In turn, this decreases the need for surgical interventions and potentially mitigates the need for more extensive, reconstructive procedures.[18]

The lower surgical intervention rate, particularly for reconstructive surgeries, further underscores the potential of the hip surveillance program to optimize conservative management and reduce the burden of invasive interventions. Reconstructive surgeries carry the largest risk of postoperative complications; patients with CP are at a 65% chance of developing postoperative complications compared with non-CP patients.[23] Some studies indicate increased risk of complications such as osteonecrosis and femur fractures.[24,25] Therefore, early detection through hip surveillance is necessary to minimize the need for more invasive surgical interventions. The study results regarding surgical intervention rate are again comparable with what has been reported in hip surveillance programs in other countries.[18,23]

Finally, the ability to recognize at-risk patients through the use of radiographic and GMFCS data allows for better utilization of preventive, conservative management of hip displacement in patients with CP. Particularly, GMFCS has been directly correlated with MP and hip displacement severity.[10,26,27] Conservative management primarily focuses on maintaining function and decreasing muscle spasticity in this patient population. However, progression of hip displacement despite conservative measures may warrant the need for surgical intervention. Hip dislocation, as previously stated, is associated with functional decline and severe hip pain,[28,29] both of which are common in CP and indications for surgical intervention. Less invasive procedures, such as soft-tissue or tendon releases, may be used to address hip displacement before dislocation actually occurs, as opposed to reconstructive salvage procedures, where there is increased risk of postoperative complications.[30] As we are detecting hip displacement earlier and more frequently monitoring for dislocation, less invasive surgeries may delay the need for reconstructive surgeries,[31,32] which may explain the lower surgical intervention rate seen in our study.

It is essential to clarify the distinction between hip surveillance and hip screening and their roles in the diagnosis and management of CP in the context of the program implemented at the medical center in question. Hip screening aims to determine what the patient's current MP and displacement is at the time of radiographs with treatment of their current state. True hip surveillance goes beyond this by reaching out to the community, identifying patients before any presentation of hip pathology, and ensuring continued monitoring and/or interventions before any disease progression can occur. This study implemented what would be more accurately described as hip screening with continued follow-up after initial presentation. Without a true CP database where medical staff are able to follow-up with patients after a CP diagnosis, a true hip surveillance program would be difficult to fully implement. However, the results of our institution's hip screening program provide additional evidence warranting the need for true hip surveillance. Steps are currently underway to transform hip screening into a hip surveillance program. For example, additional staffing was onboarded to create a multidisciplinary CP clinic at our institution. Furthermore, with additional mid-level provider support, our institution is now better equipped to follow up with patients shortly after CP diagnosis and ensure they are receiving clinical and radiographic hip evaluation in a more timely fashion.

This study is one of the first to compare radiographic and surgical intervention trends before and immediately after implementation of a hip surveillance program for pediatric patients with CP at a US-based academic institution. Given our findings, this study provides evidence that creating a nationwide hip surveillance program would facilitate earlier detection and improve comprehensive assessment of patients with CP, which would, in turn, improve outcomes and quality of life for patients with CP. Nevertheless, several limitations should still be acknowledged. This retrospective chart review analysis is subject to inherent biases and limitations associated with retrospective study designs. This includes incomplete or missing data from patient charts, possible confounding factors, and lack of randomization. Particularly, the limitations posed during the COVID pandemic from the end of 2019 through 2021 may have severely influenced the results found in the postimplementation period, especially because our institution attempted to limit exposure of the virus to this susceptible and high-risk population. In addition, families' decisions not to pursue surgery during the height of the COVID pandemic and the notable increase in patients missing and cancelling appointments because of perceived subjective concerns of COVID infections likely contributed to lower rates of reconstruction during this period. These limitations may help explain the lack of clinical significance related to the increased number of radiographs obtained and the older age at initial radiographs found after implementation of the hip screening program. Furthermore, as a single-center study, the generalizability of the findings may be limited to similar orthopaedic surgery settings. The absence of a standardized follow-up and intervention protocol may have also introduced variability in the management strategies used. Finally, data analysis should be conducted to evaluate whether there is a correlation between hip surveillance programs and improved outcomes in patients with CP.

This study aimed to observe the consequences of implementing a hip surveillance program for pediatric patients with CP at a US-based tertiary academic institution. Compared with the years before implementation of the surveillance program, there was a rise in radiographic frequency and decrease in surgical interventions after implementation. This suggests that hip surveillance programs may improve CP patient care, reducing the need for surgical intervention in favor of more conservative management. Future studies should include multicenter data that follow standardized protocols for follow-up and surgical interventions to eliminate variability in data. A prospective study evaluating the effect of standardized hip surveillance protocols on long-term outcomes in pediatric patients with CP should also be considered.

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