Radiographic hip screening for children with cerebral palsy: an imaging and reporting update

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Abstract

Children with cerebral palsy are at increased risk of hip dislocation. Detecting hip subluxation through radiographic hip screening is an essential component of hip surveillance and has been shown to prevent hip dislocations. Large-scale hip surveillance programs are being implemented nationwide, highlighting the importance of uniform technical and reporting standards.

Keywords Cerebral palsy · Children · Dislocation · Hip · Radiography · Subluxation · Surveillance

Introduction

The value of hip screening in cerebral palsy is known, with extensive multinational orthopedic studies demonstrating a hip surveillance program can prevent hip dislocations [1, 2]. Pelvis radiographs are essential to quantify the degree of hip subluxation and identify dislocations [3, 4]. Hip surveillance anteroposterior (AP) pelvis radiographs are requested by orthopedic providers and a wide range of referring clinicians who care for children with cerebral palsy, including those in neurology, complex care, physical medicine and rehabilitation, and general pediatrics. Radiologic literature on cerebral palsy hip surveillance imaging is sparse, and many pediatric radiologists are unfamiliar with the guidelines despite the central role of radiography in the screening process. It is imperative that pediatric radiologists be aware of hip surveillance guidelines as clear and standard radiographic reporting language is critical for timely orthopedic referral.

The goal of surveillance hip imaging

Children with cerebral palsy are at increased risk of hip dislocation [1]. Hypertonic hip adductors and flexors with relatively weak hip abductors exert asymmetrical muscular forces across the joint and create structural changes that displace the femoral head laterally. The incidence of hip dislocation in all children with cerebral palsy is estimated to be 15–20%, and is highest between ages 2 years and 5 years [5, 6]. Hip dislocations decrease quality of life due to pain, limited mobility, development of decubitus ulcers, difficult perineal care and chronic degenerative changes that develop over time [7]. Disease severity in cerebral palsy is classified by the Gross Motor Function Classification System (GMFCS) score, with I being the least affected and V being the most severely affected [8]. In general, a child’s risk of hip dislocation is linearly correlated with their GMFCS score, with the most severely affected individuals being at highest risk [9]. The exception is GMFCS I/II patients with type-IV hemiplegia are at higher risk for hip dislocation than would be predicted by their GMFCS score alone [9].

Although hip migration occurs gradually over time, most patients are asymptomatic until the hip is dislocated [10, 11]. Detecting hip abnormalities before dislocation requires a combination of both regular hip exams and routine radiologic evaluations [1]. Early detection is important because once
the hip has dislocated, standard reconstructive options such as pelvic osteotomies and femoral varus derotational osteotomies have a lower success rate, due to chronic bony and soft-tissue remodeling [10]. Therefore, early intervention with nonoperative and preventative surgeries are preferred because of better long-term outcomes [12, 13].

**Surveillance population and frequency**

In 2017, the American Academy for Cerebral Palsy and Developmental Medicine (AACPDM) created an online evidence-based reference guide for radiographic hip surveillance based on population data from Sweden and Australia [14]. A surveillance AP pelvis radiograph is recommended beginning at 2 years of age for all children with a GMFCS score of II or greater. Radiographic screening intervals are determined largely by GMFCS scores: the higher the GMFCS score, the shorter the interval between screening radiographs, due to the higher risk of dislocation. Non-ambulatory children and children younger than 5 years have the highest rate of annual progression of hip subluxation [15]. In general, screening radiographs are performed every 6–12 months. GMFCS I patients do not require imaging. GMFCS II children are screened until 10 years of age. Children with a GMFCS score of III or higher should have radiographic screening exams until they reach skeletal maturity [14]. With regard to hemiplegia, Winters et al. [16] first described a classification for hemiplegic gait patterns, with the least severe forms affecting only the ankle (types I and II), type III affecting the knee and ankle, and type IV being the most severe and the only form with muscle abnormalities and restricted motion about the hip. Type IV hemiplegic gait is characterized by hip flexion and internal rotation, knee flexion and ankle equinus. Hip spasticity in these patients puts them at risk for dislocation, so they should also undergo hip surveillance imaging until skeletal maturity. The AACPDM guidelines also include recommendations for patient positioning and a standard reporting measure for hip subluxation, the migration percentage. The migration percentage provides a measurement to predict the risk of hip dislocation and orthopedists have created surgical guidelines based on this tool. Hip surveillance guidelines can be accessed online [14].

**Positioning guidelines for hip surveillance anteroposterior pelvis radiography**

Positioning of cerebral palsy patients for an AP pelvis exam may be challenging because many have scoliosis and hip flexion contractures. Fifteen degrees of internal rotation of the lower extremities, which is typical for routine pelvis imaging, is often not feasible or not reproducible in children with cerebral palsy. Therefore, positioning is modified, with patellae forward and both lower extremities in a neutral position, to promote reproducibility [2, 13, 14]. A bolster should be placed behind the knees to reduce pelvic tilt (Fig. 1).

**Assessment of positioning**

The radiologist should assess the adequacy of patient positioning before interpreting the exam. An example of an appropriately positioned AP pelvis in a child with cerebral palsy is shown in Fig. 2. Suboptimal positioning should be noted in the report, especially if a change in the migration percentage from the previous exam might be explained by technical factors rather than true progressive subluxation. Fortunately, many studies investigating the influence of technical and positional factors on variability of migration percentage support the conclusion that the measurement does not significantly change with minor changes in any one positional factor (i.e. pelvic tilt, femoral rotation or hip adduction/abduction) [17–19]. If several positional factors are suboptimal, then the migration percentage may be altered.

**Assessment of pelvic tilt and rotation**

The coccyx should be in line with the pubic symphysis and the distance from the pubic symphysis to the tip of the coccyx should be 1–3 cm [20]. If the distance is outside of this range, then significant AP pelvic tilt is present. The obturator foramen and iliac wings should be symmetrical. Downward tilt of the pelvis results in narrowing of the obturator foramina and an inlet view of the pelvis, while upward tilt causes rounding of the obturator foramina and an outlet view. Although it is reasonable to evaluate tilt qualitatively, mediolateral tilt can also be quantified with the interforamina ratio, which is the ratio of the distances of the right and left obturator foramen (each distance measured between the medial and lateral foraminal borders), and should be between 0.5 and 2.0 [19].

**Assessment of lower extremity rotation**

For routine AP pelvis imaging that doesn’t involve cerebral palsy, the lower extremities are positioned with internal rotation of 15° to optimize visualization of the femoral neck. This positioning counterbalances the 15° of proximal femoral anteversion in a normal adult, and brings the femoral neck perpendicular to the x-ray beam. For a cerebral palsy surveillance AP pelvis radiograph, the lower extremities are instead positioned in neutral to maximize reproducibility and minimize under-measurement of migration percentage. Reimers and Bialik [17] found that hips in internal rotation had predictably lower migration percentages as measured on AP pelvis imaging than hips in neutral rotation, but that values only
varied by 3°, a nonsignificant difference. External rotation may falsely increase migration percentage and is also not desired. When assessing a cerebral palsy radiograph for femoral rotation, the lower extremities normally appear slightly externally rotated. Extreme external rotation is when the femoral neck is foreshortened, the greater trochanter is superimposed over the femoral neck, and the entire lesser trochanter is visible in profile. The lesser trochanter is a posterior structure, so external rotation will bring it into profile (Fig. 3).

Assessing femoral adduction and abduction

Femoral adduction and abduction are easily differentiated on an AP pelvis radiograph, with the femoral shaft moving medial in adduction and lateral in abduction. Ideally, AP pelvis imaging for cerebral palsy surveillance is obtained with the femur in a neutral position relative to adduction and abduction. Hypertonic hip adductors may limit motion and, without active repositioning of the proximal femurs, are generally held in adduction. Abduction could falsely decrease the hip migration percentage because femoral head coverage improves with medial rotation of the femoral head in the acetabulum. Moreover, frog-lateral hip radiographs are not useful in surveillance imaging and only serve to increase radiation dose.

Measurements in cerebral palsy hip migration

Migration percentage

The migration percentage is the primary measure to assess and follow hip subluxation in patients with cerebral palsy. Originally described by Reimer [18] in 1980, the migration...
percentage is a quantifiable measure of the percent of the ossified femoral epiphysis that is lateral to the ossified acetabulum, which is similar to “femoral head lateral uncovering,” though there is no standard measurement method associated with that term. There are two techniques for measuring the migration percentage. The original description uses a horizontal line through the triradiate cartilage; however, we have adopted the modified technique, which uses a line drawn horizontal to the ischial tuberosities. This modified Reimer technique accounts for pelvic obliquity, has higher inter-rater reliability and more closely approximates the risk of hip dislocation [21]. The technique is shown in Fig. 4. Using the measuring tool on a picture archiving and communication system (PACS) workstation, six lines are drawn perpendicular to the inferior ischial line on the AP pelvis radiograph. These lines are moved out, three to each femoral head: one line defines the medial margin of the femoral epiphysis, one line defines the lateral margin of the femoral epiphysis and one line defines the lateral margin of the bony acetabulum. A horizontal line connecting the lateral acetabulum line with the lateral femoral head line is drawn, giving the distance that the femoral head is lateral to the acetabulum (line A). A second horizontal line connects the medial and lateral femoral head margins, giving the total femoral head width (line B). A/B gives the percentage of femoral epiphysis lateral to the acetabulum (migration percentage).

We found this technique to be easy to learn and reproduce. Also, it is not overly cumbersome in our current practice, which requires the radiologist to perform measurements at the time of reporting. Reproducibility has been validated in the orthopedic literature, and measurement error is reported between 5% and 8% [22, 23]. Recently, methods for measuring the migration percentage were compared using digital measurements on a PACS monitor, computer-aided measurements with digital templating tools (OrthoView Digital Templating suite; Materialise OrthoView, Leuven, Belgium), and a free mobile device application using the camera and touchscreen (HipScreen; Shriners Hospitals for Children, Sacramento, CA) [24]. Results found that intrarater reliability and inter-rater reliability for each measurement method were excellent (intraclass correlation coefficient [ICC]: 0.972–0.990), though the mean time to complete the measurement was significantly faster with the computer-aided and mobile application methods (73–80 s) compared with the PACS digital method (151 s) [24]. Thus, it may be acceptable to adopt one of these time-saving methods in lieu of archiving measurements in PACS.

**Head–shaft angle**

Children with cerebral palsy are also prone to abnormal proximal femoral geometry, due to the abnormal muscular forces exerted across the joint, with hypertonic hip flexors and adductors. Coxa valga describes an increased angle between the femoral neck and shaft, which is common in cerebral palsy and can be measured as the neck–shaft angle. In an open physes, however, the femoral head is also in valgus with relation to the neck and shaft; therefore, the neck–shaft angle may

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**Fig. 4** A measurement technique for hip migration percentage using the anteroposterior view of the pelvis in a 10-year-old girl with cerebral palsy. a A horizontal line is drawn along the ischia using the measuring tool on a picture archiving and communication system (PACS) workstation. b Six lines are then drawn perpendicular to the ischial line. An angle calculator can be used to ensure lines are drawn 90° to the ischial line. It is most efficient to draw these lines next to each other in the midline to ensure they are all parallel. The lines are moved out to frame the medial (solid lines) and lateral (dotted lines) borders of each femoral head, with the final line for each hip placed along the lateral border of the bony acetabulum (dashed lines). Horizontal lines A and B are drawn to calculate the percent of femoral head lateral to the bony acetabulum: \( \frac{A}{B} \times 100 = \text{migration percentage} \). Adapted from [18, 21]
underestimate the true deformity [25]. The head–shaft angle takes the femoral head orientation into account in an open physis (Fig. 5). An increase in head–shaft angle has been shown to be a risk factor for hip subluxation [25]. Unlike the neck–shaft angle, the head–shaft angle is relatively insensitive to internal and external rotation of the femur [26]. Finlayson et al. [27] found that in children with cerebral palsy and GMCSF scores of III–V, femurs with a head–shaft angle >164.5° were nearly two times more likely to go on to dislocate than those with a head–shaft angle ≤164.5° [27]. Figure 6 illustrates the head–shaft angle and neck–shaft angle measurements in a child with cerebral palsy.

We do not measure and include the head–shaft angle in our radiology reports due to time constraints. Though our orthopedists believe this measurement has value, surgical decision making is primarily driven by the migration percentage not the head–shaft angle.

**Acetabular morphology**

Acetabular dysplasia occurs in cerebral palsy due to abnormal lateral positioning of the femoral head within the acetabulum. While the acetabular index is the most commonly used quantifiable measure of acetabular dysplasia in cerebral palsy on an AP pelvis radiograph, it is not specifically reported as part of our surveillance imaging. The acetabular index is the angle formed by the intersection of the horizontal line (Hilgenreiner’s line) through the base of the triradiate cartilages and a line drawn tangent to the medial and lateral acetabular walls. The acetabular index is normally <22° at birth and <22° at 1 year of age [28]. Acetabular deficiency coincides with the direction of femoral head subluxation and dislocation, which is predominantly posterosuperior. However, the acetabular index only reflects the degree of lateral bony coverage and cannot accurately quantify the posterior acetabular dysplasia that predominates in cerebral palsy. Three-dimensional (3-D) cerebral palsy modeling has shown even patients with mild disease show posterior wall deficiency compared with normal controls [29]. Worsening disease severity predicts progressive acetabular deficiency, which eventually affects the anterosuperior and superolateral quadrants as well [29]. Hägglund et al. [30] tried to determine a cutoff value beyond which corrective intervention on the hip should be performed based on the acetabular index, which historically has been between 27° and 30°. Two hundred and seventy-two children with cerebral palsy were evaluated with AP pelvis radiographs at least yearly per surveillance guidelines, and acetabular index and migration percentage were measured on all of them. Only 21% developed acetabular dysplasia as defined as an acetabular index of ≥27°, while 30% developed femoral head subluxation with a migration percentage ≥30%. The authors found that many hips with a migration percentage ≥30% had a normal acetabular index. Femoral head lateral movement also preceded acetabular dysplasia in patients with both increased migration percentages and acetabular indices, and hip subluxation was common without acetabular dysplasia [31]. Park et al. [32] looked at 72 patients who underwent varus derotational osteotomy to correct hip subluxation or dislocation in cerebral palsy and found that the preoperative acetabular index did not predict surgical success or recurrent dislocation. A preoperative migration percentage of 61.8% and a postoperative migration percentage of 5.1% did, however, predict poorer postoperative outcomes, which the authors concluded may help determine which patients may need simultaneous pelvic osteotomy. Thus, we also do not measure the acetabular index as it appears less sensitive and specific than the migration percentage in detecting hip disease, does not predict the need for surgery and does not forecast surgical outcomes.

**Reporting in cerebral palsy hip migration**

We developed a succinct standard reporting template for cerebral palsy hip surveillance (Fig. 7). The Findings section guides migration percentage reporting of each hip with a line for reporting other abnormalities of the proximal femurs and pelvis. Auto-text terminology has been standardized to avoid confusion by interpreting physicians, many of whom are non-orthopedic. Standardized reports allow ready comparison to follow children from infancy to skeletal maturity.

The Impression section of our radiology report template requires a risk category for each hip based on the migration
percentage. Risk categories were included at the request of our orthopedic surgeons because they reflect the risk of progression to hip dislocation based on existing literature, facilitate appropriate referrals and also serve as broad treatment-based guidelines. Literature shows a clear correlation between an increasing migration percentage and the risk of worsening hip migration and progression to dislocation [7, 15, 30, 31]. Each risk category (above low risk) represents a potential point of intervention. Surgical referral is recommended at a migration percentage of 30% or greater, though it may only result in decreased surveillance intervals from 12 months to 6 months because these hips may stabilize [14]. The literature shows the majority of children with a migration percentage of 40% or greater progressed, so this is the generally accepted threshold for operative intervention [30]. Miller and Bagg [31] found all hips with a migration percentage ≥60% went on to dislocate in their cohort; thus, surgical intervention is recommended in all children with migration percentages of ≥60%. This data drives our risk stratification for each hip, which we place into one of 4 broad categories: (1) a migration percentage of <30% is low risk for dislocation, (2) 30–59% is moderate risk for dislocation, (3) ≥60% is high risk for dislocation, and (4) a dislocated hip. Variability in patient anatomy and positioning introduces inconsistencies in measurement, likely

Fig. 6 Anteroposterior pelvis radiographs in a girl with gross motor function classification system level V (GMFCS V) cerebral palsy. a A radiograph performed at 3 years old shows left hip lateral migration (migration percentage, not drawn, 54%). b Neck–shaft angle and head–shaft angle measurement. The neck–shaft angle of the right hip is increased (168°) and the head–shaft angle is increased (175°) on the left. c At 5 years old, the left hip shows progressive lateral migration (migration percentage, not drawn, 71%), high risk for dislocation. Left acetabular dysplasia has also developed. The right hip remains low risk for dislocation with the migration percentage <30%

Fig. 7 A standardized reporting template created for screening hip radiographs in children with cerebral palsy. The Findings section requires quantification of hip migration using a numeric value, the migration percentage (MP). The Impression section requires a risk category assignment.

FINDINGS

HIPS and PROXIMAL FEMURS

RIGHT Hip:
Migration Percentage (MP): [ ]%
Proximal Femur: [No acute abnormality]

LEFT Hip:
Migration Percentage (MP): [ ]%
Proximal Femur: [No acute abnormality]

IMPRESSION:

LEFT HIP: [pick list: low risk, moderate risk, high risk]
RIGHT HIP: [pick list: low risk, moderate risk, high risk]

Note: Risk categories based on Migration Percentage (MP):
<30% MP = low risk for hip subluxation or dislocation
30–59% MP = moderate risk for hip dislocation
≥60% MP = high risk for hip dislocation
more pronounced in those with more severe hip disease. The extent to which this affects the patient’s risk category is likely minor, however, given that each category is a range of 30%.

Controversies in interpretation and reporting

Literature regarding what degree of hip migration should be considered within normal limits is sparse, particularly in children with cerebral palsy who have abnormal forces acting on their hips, forces that are dynamic and change with age and ambulation. Reimers [18] did report that in normal children the 90th percentile for migration percentage at 4 years old was 10% with changes in migration of less than 1% per year. So, one could argue for using 10% as the cutoff for normal migration percentage in children with cerebral palsy as well, though many orthopedic authors like Miller and Bagg [31] consider any migration percentage less than 30% to be normal.

Initially, we limited our Impression section to one of two generic statements: “abnormal hips,” for all hips with a migration percentage >0%, or “normal,” for all hips with no measurable migration. Yet children with a measurable migration percentage >0% but <30% require observation only, without orthopedic referral, and the term “abnormal hips” was creating unnecessary concern among patients and their families with migration percentage <30%. Our orthopedic colleagues noted an increase in unnecessary referrals and concerned parent phone calls (parents can view reports), prompted by impressions termed “abnormal hips” in children with cerebral palsy with a migration percentage <30%. We recognized that normal versus abnormal was an academic discussion and ultimately chose to eliminate normal from our template for this reason; the clinical import of the screening pelvis radiograph is not to separate normal from abnormal but to risk stratify a patient’s hips. More important in patients with a migration percentage <30% is not the exact degree of migration, but the rate of change over time, which may better reflect the risk of progression to dislocation [9]. Greater than 10% increase per year has been cited as significant [33].

Assigning a risk category to each hip based on the migration percentage is controversial, though radiographic risk stratification is meant only to guide, not restrict, a physician’s treatment options. Clinicians must weigh other factors contributing to the risk of dislocation, including patient age, disease severity and rate of change in migration percentage, against the risk of intervention, quality of life and goals of care. Hips with an increasing migration percentage over several studies may be at higher risk for dislocation than those that remain unchanged. In our practice, the radiologic hip risk stratification serves to set a cutoff value for when a patient should be referred to orthopedics, which is when the migration percentage is 30% or greater, and to help clinicians counsel families on potential treatment. We recently surveyed our referring providers regarding radiology reporting in cerebral palsy hip surveillance to determine if our migration percentage and risk category reporting was perceived as helpful or detrimental. Of the eight clinicians who responded to the survey and who order cerebral palsy surveillance hip radiographs, all answered yes to the question “Do you think inclusion of migration percentage and risk categories in radiology reports is helpful?” Cerebral palsy providers commented that migration percentage reporting provided “greater consistency in the reports, making it easier to quickly look back and compare prior measurements,” “better guidelines of when to refer to orthopedics” and “better information to discuss with families.”

There has been debate over the most appropriate placement of the longitudinal lateral acetabular line, also known as Perkin’s line (Fig. 4), when measuring the migration percentage. In adults, the lateral sourcil represents the true weight-bearing aspect of the lateral acetabulum, not the lateral-most bony rim. In young children, however, the sourcil is immature or non-formed and, if used as the lateral margin of the acetabulum, overestimates the migration percentage and introduces variability over time [34]. To make matters more confusing, an acetabular variant termed the Gothic arch has also been described in children with cerebral palsy. The Gothic arch is hypothesized to result from lateralized femoral head pressure that inhibits normal lateral acetabular ossification. It is characterized by diminished ossification of the superolateral aspect of the acetabular rim, absence of the normal sclerotic lateral sourcil rim, and may sometimes be accompanied by a focal erosion or upturning of the lateral-most acetabular rim seen on radiography, located just medial to the lateral bony margin (Fig. 8). Although it is described radiographically, there is relatively little published in the literature that depicts its true 3-D characteristics [35]. Some experts have advocated using the apex of the Gothic arch as the lateral margin of the acetabulum, when present, to measure the migration percentage, though we have agreed to abandon this nuance due to flow difficulty management without quantitative measurement, and was cited as a common indication for unnecessary referrals to our orthopedic colleagues from pediatricians unfamiliar with the term. Analogous to language standardization in other
Radiology reporting systems, such as the Breast Imaging Reporting and Data System (BI-RADS) and the Thyroid Imaging Reporting and Data System (TI-RADS), large-scale pediatric surveillance programs, such as cerebral palsy hip surveillance, also stand to gain from similarly structured reporting systems.

Additionally, we discourage the use of lateral uncovering as an alternative to migration percentage in cerebral palsy reporting. There is no standard technique for measuring lateral uncovering, which introduces variability in measurement and is not part of the cerebral palsy hip surveillance lexicon.

Management of cerebral palsy hip disease

Children with cerebral palsy are managed by a variety of pediatric providers based on needs. Some patients may primarily see a general pediatrician, while others require care by physicians specializing in neurology, complex care, or physical medicine and rehabilitation. These providers are responsible for ensuring appropriate hip surveillance imaging is obtained at the correct intervals. Many children with cerebral palsy will never need referral to an orthopedic surgeon.

In general, orthopedic referral is recommended when the migration percentage is 30% or greater, and surgical intervention is considered when the migration percentage is >40% [2, 30, 33]. When the migration percentage is between 40% and 60%, the surgeon may offer staged procedures starting with soft-tissue releases such as adductor tenotomies, followed by bony reconstructive surgery if the migration percentage does not stabilize [33]. The surgical decision is based not only on the migration percentage, but the rate of change over time, the range of hip abduction and other clinical factors. Reconstructive surgeries, also called redirectional osteotomies, include femoral varus derotational osteotomies, which serve to redirect the femoral head inferomedially toward the acetabulum, and pelvic osteotomies, which extend the acetabulum inferolaterally, for improved femoral head coverage (Fig. 9). Combined surgeries have the highest success rates [37]. Salvage surgeries are reserved for longstanding hip dislocations with 10–44% of patients experiencing continued pain after surgery [6].

Postoperative cerebral palsy hips

Patients require continued surveillance even after combined redirectional osteotomies as the risk of re-subluxation has been reported at 7% [37]. Children with cerebral palsy experience almost twice as many postoperative complications as patients without cerebral palsy when undergoing hip osteotomies, according to a study by DiFazio et al. [38]. The majority of these complications are non-orthopedic in cerebral palsy patients, while patients without cerebral palsy experienced predominantly orthopedic complications. The most common postoperative orthopedic complication in cerebral palsy patients was fracture in one study [39], delayed bone healing and heterotopic bone in another [38], while yet another study showed failure of femoral hardware, re-dislocation and femur fracture of the operated limb as the most common complications [40]. The radiologist should assess postoperative radiographs for hardware integrity, healing, fracture, heterotopic bone and then measure a migration percentage. Ambulatory status also correlates with postoperative

Fig. 8 Gothic arch morphology of the acetabulum, indicative of chronic acetabular dysplasia in cerebral palsy. a, b An anteroposterior pelvis radiograph (a) in a 11-year-old boy with cerebral palsy demonstrates a right acetabular “Gothic arch.” The right acetabulum is shallow and vertically oriented. The right acetabular sourcil is indistinct with a focal erosion at the lateral aspect (arrow), which has been likened to the pointed arch of a Gothic cathedral (b)
complications, with wheelchair-bound children at higher risk of postoperative complications [39]. The most common non-orthopedic complications in cerebral palsy patients are poor wound healing, skin infections and decubitus ulcers [38].

Conclusion

Radiographic evaluation of the hips in children with cerebral palsy is an essential component of a hip surveillance program. The pediatric radiologist plays an important role in the care of children with cerebral palsy hip disease and should be familiar with current technical measurement and reporting guidelines.

Acknowledgments Figure 5 is reprinted from [27] which is an open access article (original publisher: Springer Nature) under the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/).

Declarations

Conflicts of interest None

References

1. Hagglund G, Alriksson-Schmidt A, Lauge-Pedersen H et al (2014) Prevention of dislocation of the hip in children with cerebral palsy: 20-year results of a population-based prevention programme. Bone Joint J 96-B:1546–1552
2. Wynter M, Gibson N, Willoughby KL et al (2015) Australian hip surveillance guidelines for children with cerebral palsy: 5-year review. Dev Med Child Neurol 57:808–820
3. Huser A, Mo M, Hosseinizadeh P (2018) Hip surveillance in children with cerebral palsy. Orthop Clin North Am 49:181–190
4. Scrutton D, Baird G (1997) Surveillance measures of the hips of children with bilateral cerebral palsy. Arch Dis Child 76:381–384
5. Hagglund G, Andersson S, Duppe H et al (2005) Prevention of severe contractures might replace multilevel surgery in cerebral palsy: results of a population-based health care programme and new techniques to reduce spasticity. J Pediatr Orthop B 14:269–273
6. Kolman SE, Ruzbarsky JJ, Spiegel DA, Baldwin KD (2016) Salvage options in the cerebral palsy hip: a systematic review. J Pediatr Orthop 36:645–650
7. Bagg MR, Farber J, Miller F (1993) Long-term follow-up of hip subluxation in cerebral palsy patients. J Pediatr Orthop 13:32–36
8. Palisano R, Rosenbaum P, Walter S et al (1997) Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neurol 39:214–223
9. Pruszczynski B, Sees J, Miller F (2016) Risk factors for hip displacement in children with cerebral palsy: systematic review. J Pediatr Orthop 36:829–833
10. Shore B, Spence D, Graham H (2012) The role for hip surveillance in children with cerebral palsy. Curr Rev Musculoskelet Med 5:126–134
11. Flynn JM, Miller F (2002) Management of hip disorders in patients with cerebral palsy. J Am Acad Orthop Surg 10:198–209
12. Presedo A, Oh C-W, Dabney KW, Miller F (2005) Soft-tissue releases to treat spastic hip subluxation in children with cerebral palsy. J Bone Joint Surg Am 87:832–841
13. Kiapkos N, Brostrom E, Hagglund G, Astrand P (2019) Primary surgery to prevent hip dislocation in children with cerebral palsy in Sweden: a minimum 5-year follow-up by the national surveillance program (CPUP). Acta Orthop 90:495–500
14. O’Donnell M, Mayson T, Miller S et al (2017) Hip surveillance. Bottom line ‘evidence-informed’ recommendations for the hip surveillance in individuals with cerebral palsy. https://www.aacpdm.org/UserFiles/file/hip-surveillance-care-pathway.pdf. Accessed 27 July 2021
15. Terjesen T (2006) Development of the hip joints in unoperated children with cerebral palsy: a radiographic study of 76 patients. Acta Orthop 77:125–131
16. Winters TF Jr, Gage JR, Hicks R (1987) Gait patterns in spastic hemiplegia in children and young adults. J Bone Joint Surg Am 69:437–441
17. Reimers J, Bialik V (1981) Influence of femoral rotation on the radiological coverage of the femoral head in children. Pediatr Radiol 10:215–218
18. Reimers J (1980) The stability of the hip in children. A radiological study of the results of muscle surgery in cerebral palsy. Acta Orthop Scand Suppl 184:1–100
21. Hagglund G, Goldring M, Hermanson M, Rodby-Bousquet E (2018) Pelvic obliquity and measurement of hip displacement in children with cerebral palsy. Acta Orthop 89:652–655

22. Parrott J, Boyd RN, Dobson F et al (2002) Hip displacement in spastic cerebral palsy: repeatability of radiologic measurement. J Pediatr Orthop 22:660–667

23. Shore BJ, Martinkevich P, Riazi M et al (2019) Reliability of radiographic assessments of the hip in cerebral palsy. J Pediatr Orthop 39:e536–e541

24. Kulkarni VA, Davids JR, Boyles AD et al (2018) Reliability and efficiency of three methods of calculating migration percentage on radiographs for hip surveillance in children with cerebral palsy. J Child Orthop 12:145–151

25. Forooah A, McCarthy JJ, Yucha D et al (2009) Head–shaft angle measurement in children with cerebral palsy. J Pediatr Orthop 29:248–250

26. Hermanson M, Hägglund G, Riad J, Wagner P (2015) Head–shaft angle is a risk factor for hip displacement in children with cerebral palsy. Acta Orthop 86:229–232

27. Finlayson L, Czuba T, Gaston MS et al (2018) The head shaft angle is associated with hip displacement in children at GMFCS levels III–V — a population based study. BMC Musculoskelet Disord 19:356

28. Tönnis D, Brunken D (1968) Differentiation of normal and pathological acetabular roof angle in the diagnosis of hip dysplasia. Evaluation of 2,294 acetabular roof angles of hip joints in children. Arch Orthop Unfallchir 64:197–228

29. Chung MK, Zulkarnain A, Lee JB et al (2017) Functional status and amount of hip displacement independently affect acetabular dysplasia in cerebral palsy. Dev Med Child Neurol 59:743–749

30. Hägglund G, Lauge-Pedersen H, Persson M (2007) Radiographic threshold values for hip screening in cerebral palsy. J Child Orthop 1:43–47

31. Miller F, Bagg MR (1995) Age and migration percentage as risk factors for progression in spastic hip disease. Dev Med Child Neurol 37:449–455

32. Park H, Abdel-Baki SW, Park K-B et al (2020) Outcome of femoral varus derotational osteotomy for the spastic hip displacement: implication for the indication of concomitant pelvic osteotomy. J Clin Med 9:256

33. Dobson F, Boyd RN, Parrott J et al (2002) Hip surveillance in children with cerebral palsy. Impact on the surgical management of spastic hip disease. J Bone Joint Surg Br 84:720–726

34. Kim HT, Kim JI, Yoo CI (2000) Diagnosing childhood acetabular dysplasia using the lateral margin of the sourcil. J Pediatr Orthop 20:709–717

35. Roach JW, Hobatho MC, Baker KJ, Ashman RB (1997) Three-dimensional computer analysis of complex acetabular insufficiency. J Pediatr Orthop 17:158–164

36. Miller S, Habib E, Bone J et al (2021) Inter-rater and intrarater reliabilities of the identification of a "gothic arch" in the acetabulum of children with cerebral palsy. J Pediatr Orthop 41:6–10

37. Allassaf N, Saran N, Benaroch T, Hamdy RC (2018) Combined pelvic and femoral reconstruction in children with cerebral palsy. J Int Med Res 46:475–484

38. DiFazio R, Vessey JA, Miller P et al (2016) Postoperative complications after hip surgery in patients with cerebral palsy: a retrospective matched cohort study. J Pediatr Orthop 36:56–62

39. Stasikelis PJ, Lee DD, Sullivan CM (1999) Complications of osteotomies in severe cerebral palsy. J Pediatr Orthop 19:207–210

40. Terjesen T (2019) Femoral and pelvic osteotomies for severe hip displacement in nonambulatory children with cerebral palsy: a prospective population-based study of 31 patients with 7 years' follow-up. Acta Orthop 90:614–621

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