FİZİKSEL TIP VE REHABİLİTASYON BİLİMLERİ DERGİSİ
Journal of Physical Medicine and Rehabilitation Sciences J PMR Sci. 2021;24(3):277-83

ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH DOI: 10.31609/jpmrs.2021-83191

Botulinum Toxin-A Injection for Hip Adductor Spasticity in Children with Cerebral Palsy: A Retrospective Study

Kalça Adduktor Spastisitesi Olan Serebral Palsili Çocuklarda Botulinum Toksin-A Enjeksiyonu: Retrospektif Bir Çalışma

Esra SARIGEÇİLİ[a], Melek SEZGİN[b], Ünzüle HANBABA[b], Didem DERİCİ YILDIRIM[c], Çetin OKUYAZ[d]

[a]Clinic of Pediatric Neurology, Adana City Training and Research Hospital, Adana, TURKEY
[b]Department of Physical Medicine and Rehabilitation, Mersin University Faculty of Medicine, Mersin, TURKEY
[c]Department of Biostatistics, Mersin University Faculty of Medicine, Mersin, TURKEY
[d]Department of Pediatric Neurology, Mersin University Faculty of Medicine, Mersin, TURKEY

ABSTRACT Objective: To assess clinical and radiological effectiveness of botulinum neurotoxin-A (BoNT-A) injection in children with cerebral palsy (CP) with spasticity in the hip adductor muscles. CP is a nonprogressive central nervous system disease that occurs in the intrauterine or early infantile period that leads to posture or motor dysfunction and activity and movement-limitation. **Material and Methods:** This study was designed as a retrospective. Patients who received BoNT-A injections consecutively during one year due to spasticity in bilateral hip adductor muscles were identified. For clinical evaluation, distance between the knees, Modified Ashworth Scale (MAS), and Gross Motor Function Classification System (GMFCS) scores were recorded from the patient files. Radiological evaluation was performed by measuring acetabular index (AI) and collo-diaphyseal angle (CDA) in the A/P pelvis radiographs available in the patient registry system. **Results:** The mean age of 20 patients (boys:12, girls:8) included in the study was 84.8±20.9 months (minimum-maximum: 48-120 months). Seven patients had diplegic, 7 patients quadriplegic and 6 patients mixed type involvement. The MAS and GMFCS scores of the patients were found to be decreased significantly at the third and twelfth month after the first injection compared to pre-treatment (right p:0.007, left p:0.005 and p:0.002, respectively). Similarly, the distance between knees had increased statistically at the third and twelfth month ($p<0.001$). However, in the radiological evaluation, AI and CDA measurements were not statistically different after 3 months and 12 months compared to pre-treatment ($p>0.05$). **Conclusion:** This study demonstrated that sequential BoNT-A injections may provide clinical improvement and prevent radiological progression of the hip in children with CP with bilateral hip adductor spasticity.

Keywords: Cerebral palsy; hip adductor muscle; spasticity; and botulinum toxin-A; children

ÖZET Amaç: Kalça adduktor kas spastisitesi olan serebral palsili (SP) çocuklarda botulinum toksin-A'nın klinik ve radyolojik etkinliğini araştırmak. SP intrauterin ya da erken infantil dönemde meydana gelen hareket ve postür bozukluğuna yol açan santral sinir sisteminin nonprogressive bir hastalığıdır. **Gereç ve Yöntemler:** Çalışma retrospektif olarak dizayn edildi. Kalça adduktor kas spastisitesi olması sebebi ile 1 yıl süresince düzenli BoNT-A enjeksiyonu uygulanan hastalar belirlendi. Klinik değerlendirme için, dizler arası mesafe, modifiye Asworth Skalası (MAS) ve Kaba Motor Fonksiyon Sınıflandırma Sistemi (KMFSS) hasta dosyalarından kaydedildi. Radyolojik değerlendirme hastane kayıt sisteminde bulunan anterior-posterior pelvis radyografisinde asetabular indeks (AI) ve kollo-diafizer açı (KDA) ölçümü yapılarak belirlendi. **Bulgular:** Çalışmaya dâhil edilen 20 hastanın ortalama yaşları (erkek: 12, kız: 8) 84,8±20,9 aydı (minimum-maksimum: 48-120 ay). Yedi hasta diplejik, 7 hasta kuadriplejik ve 6 hasta mix tip SP'idi. Hastaların MAS ve KMFSS skorları ilk enjeksiyondan sonraki 3. ve 12. ayda büyük ölçüde azaldı (sağ p:0,007 sol p:0,005 ve p:0,002 idi). Benzer şekilde, 3. ve 12. ayda dizler arası mesafe de giderek arttı ($p<0,001$). Ancak radyolojik değerlendirmede AI ve KDA'da anlamlı düzelme görülmedi ($p>0,05$). **Sonuç:** Bu çalışmada, kalça adduktor kas spastisitesi olan SP'li çocuklarda seri BoNT-A enjeksiyonunun klinik bir düzelme sağladığı ve radyolojik olarak ise progressif kalça dislokasyonunu önlediği gösterilmiştir.

Anahtar Kelimeler: Serebral palsi; kalça adduktor kas; spastisite; botulinum toksin-A; çocuklar

Correspondence: Esra SARIGEÇİLİ
Clinic of Pediatric Neurology, Adana City Training and Research Hospital, Adana, TURKEY/TÜRKİYE
E-mail: sarigeciliesra@gmail.com

Peer review under responsibility of Journal of Physical Medicine and Rehabilitation Science.

Received: 20 Mar 2021 ***Received in revised form:*** 26 Apr 2021 ***Accepted:*** 27 Apr 2021 ***Available online:*** 05 Apr 2021

Cerebral palsy (CP) is a permanent but not progressive central nervous system (CNS) disease that occurs in the intrauterine period or in the early infantile period that leads to posture-motor dysfunction and also leads to activity and movement-limitation.[1] While the prevalence of CP in developed societies is 2-2.5 per 1,000 live births; it is 4.4 per 1,000 live births in our country.[2,3]

In children with CP, hip dislocation is the second most common condition after pes equinovarus deformity of the feet.[4] While its frequency was 6% in the ambulatory group; it increases to 60% in the non-ambulatory group.[5,6] Hip dislocation develops due to spasticity and contraction especially in adductor and flexor muscles. The score that evaluates the motor function and mobility used in CP patients is the Gross Motor Function Classification System (GMFCS) and the risk of hip dislocation increases with increasing GMFCS score in patients. Especially the patients who have GMFCS level 4 or 5 cannot sit or walk independently and they need help even in their daily activities.[5,7,8]

Although CP is a neurologically non-progressive disease, it is a progressive disease for the musculoskeletal system. Over time, contractures, bone torsional deformities and joint instability problems occur in muscle-tendon units. CP patients don't have any complaints at the beginning (lateral hip displacement) until the hip dislocation and pain are settled.[9]

With the dislocation of the hip, the angle between the femoral shaft and the femoral neck increases anatomically with femoral anteversion (collo-diaphyseal angle). This has been shown to be directly related to the GMFCS score.[10] In the previous studies, it was stated that progressive restriction in abduction and flexion deformity are among the early indicators of hip instability.[11]

The treatment of spasticity in CP patients includes physical therapy (PT) and rehabilitation applications, usage of orthoses, drug treatments, botulinum neurotoxin-A (BoNT-A) injections and surgical methods.[12] Among the treatments in focal spasticity, BoNT-A injection is aimed to reduce the muscle spasticity. It has been shown that it has corrected walking dysfunction in the ambulatory group whereas in the non-ambulatory group (GMFCS 4-5), it has relieved muscle pain, reduced joint subluxations, increased compliance with PT, enabled independent sitting and provided convenience in daily care for the caregiver.[8,13,14] In children with CP, spasticity at the hip adductor muscles causes difficulty in sitting, impaired walking, pain, problems with perineal hygiene, even progressive hip subluxation and dislocation.[15]

A number of studies have demonstrated that injections of BoNT-A are effective in reducing spasticity and improving function in children with CP. The aim of this retrospective study was to assess the clinical and radiological effectiveness of consecutive BoNT-A injections in one-year period for the hip adductor spasticity in children with CP.

MATERIAL AND METHODS

This study was designed as retrospective. The files of patients who were followed up with a diagnosis of CP between the years 2010-2019 in the Child Neurology and Physical Medicine and Rehabilitation outpatient clinics of Mersin University Hospital were scanned. The patients who received consecutive BoNT-A injections during one year due to spasticity in the bilateral hip adductor muscles were detected. Among these, the patients whose sequential clinical and radiological evaluations were available in their files were included in the study. All patients had been evaluated before treatment, from the first injection 3 months and 12 months later. During a 1-year period, those who were changed antispasticity drug or dose; those with a previous hip dislocation or hip operation or selective dorsal rhizotomy history were excluded in the study.

Along with demographic data, for clinical evaluation distance between the knees, Modified Ashworth Scale (MAS), and GMFCS scores were recorded from the patient files. Radiological evaluation was performed by measuring acetabular index (AI) and collo-diaphyseal angle (CDA) in the A/P pelvis radiographs available in the patient registry system (Figure 1). MAS and knee-distance test were used for spasticity evaluation of the hip adductor muscles. MAS rate evaluated as; 0: no tonus increase,

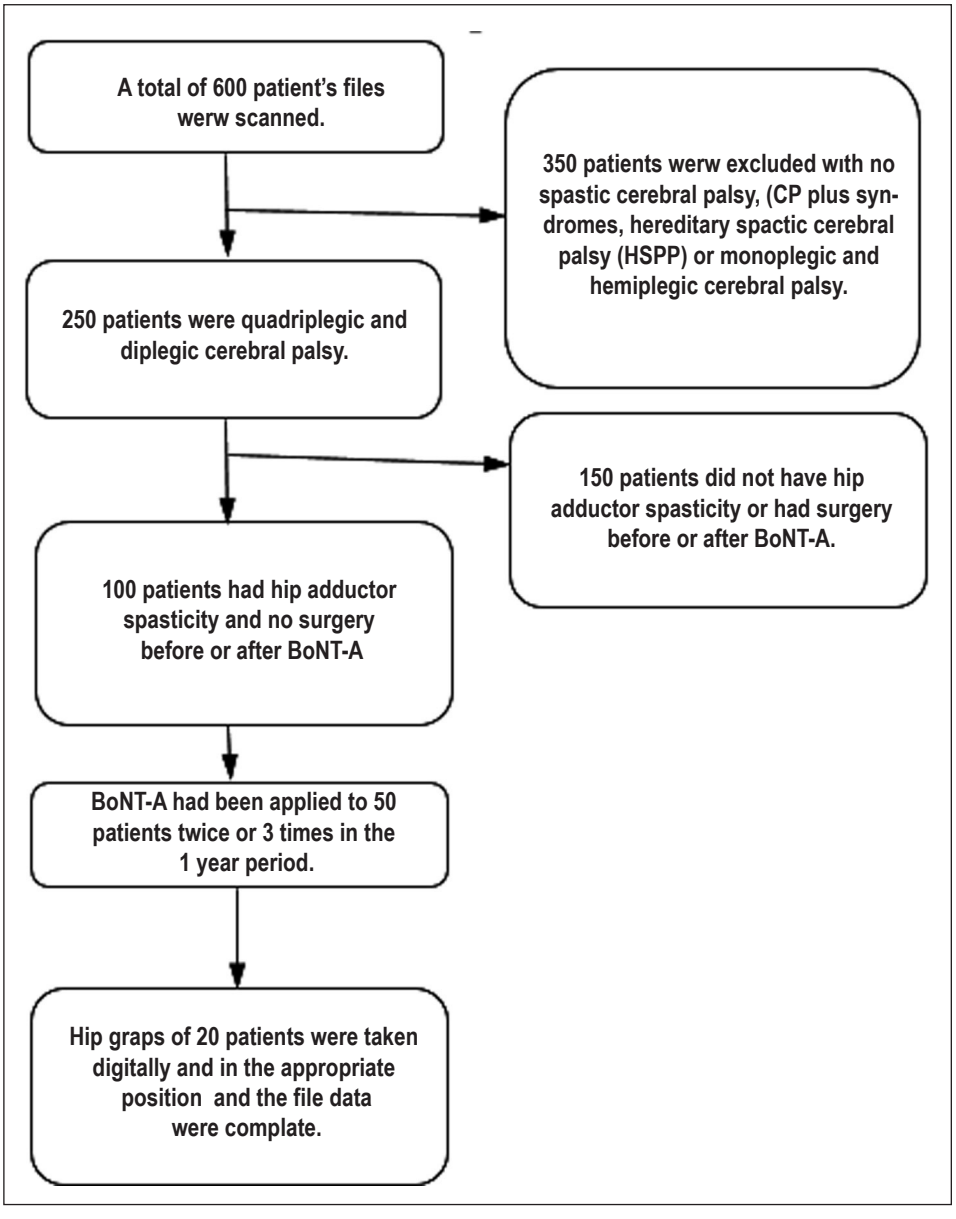

FIGURE 1: The inclusion and exclusion criteria of the patients.

1: resistance at the end of the range of motion, +1: resistance over less than half of the range of motion, 2: muscle tone increased over the entire range of joint, but can be moved, 3: obvious tonus increase that complicates passive movement, 4: rigidity in flexion and extension. Knee-distance test measures the distance between the medial femoral condyles during maximal abduction. The test was performed with both slow and fast passive abduction movement of the limbs. The test is used for evaluating the joint clearance in the fast and slow phase of flexion and extension. If hip adductor spasticity is present, there will be a large difference in the range of motion between slow and fast movement.

Among the radiological examinations, the AI; shows the angle between the Hilgenreiner's line and the acetabular roof. Normal AI is 30° at the first year of life, 25° at age 1-5 years, and 20° at older ages. Until thirty months old, AI is generally normal in CP patients. After that, it gradually increases. CDA is the angle between the neck and body of the femur.[16] While the GMFCS score increases in patients with

CP, the CDA score also increases as well. In our study, while measuring these angles, the patients were given the correct position (where the anterior or posterior posture of the pelvis was appropriate), and the measurement points on the computer were correctly determined by fixing them on the A/P pelvis radiograph and measured with the appropriate technique. Numerical values were obtained for each patient (Figure 2).

Ethics committee approval was obtained from Mersin University Ethics Committee for the study with the decision dated 24/07/2019 and numbered 2019/317. The study was performed in accordance with Helsinki Declaration.

STATISTICAL METHODS

Statistical analyses were performed using the Statistica 13.3.1 software. The Shapiro-Wilk test was performed to test the suitability of normal distribution. Comparisons for continuous variables were made by the Mann-Whitney test or Independent sample t-test according to normality assumption. Continuous data were summarized as mean [standard deviation] or median (percentiles) in dependent to distribution assumption. Categorical data were expressed as count and percentage. In order to examine the temporal difference between more than two dependent measurements, variance analysis was used when the distribution condition was met, and the Friedman test was used if not. A p value of <0.05 was considered to be significant.

RESULTS

The average age of 20 patients (boys: 12, girls: 8) included in the study was 84.8±20.9 months (minimum-maximum: 48-120 months). Seven patients (35%) were spastic diplegic, 7 patients (35%) were spastic quadriplegic, 6 patients (30%) were mixed-type CP. All patients have received a PT program of 90-120 sessions (3-5 sessions/week, 45-60 minutes) for 1 year (Table 1).

BoNT-A injections had been applied twice to 9 patients and 3 times to 11 patients in the 1-year period. In 9 patients, the second injection has been performed from the first injection an average of 6,5 months later (minimum-maximum: 4-9 months), in 11 patients, the second injection a mean 4,9 months later (minimum-maximum: 4-7 months) and the third injection a mean 10,2 months later (minimum-maximum: 8-11 months) has been performed. All applications have been made under anesthesia and electrical stimulation. Abobotulinum toxin A (10-15 U/kg/ muscle) has been administered to 3 patients, Onabotulinum toxin A (3-4 U/kg/muscle) to 16 patients, and both drugs to 1 patient.

It was determined that the MAS scores of the patients decreased statistically significantly at the third and twelfth months after the first injection compared to pre-treatment (right p:0.007, left p:0.005). Similarly, the distance between the knees in both flexion and extension had increased significantly at the third and twelfth months after the first injection (p<0.001) (Table 2). The GMFCS scores were found to be significantly decreased at the third and twelfth months compared to pre-treatment

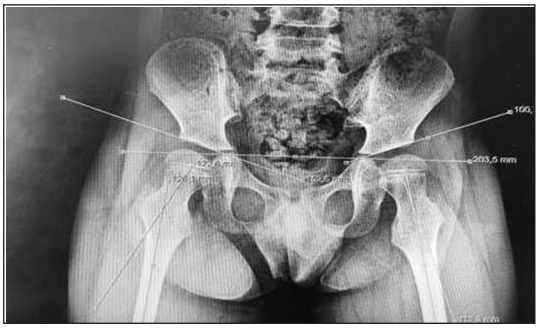

FIGURE 2: Acetabular index and collo-diaphyseal angle measurement methods.

TABLE 1: Clinical and demographic data of patients.

	Mean/number (n)	Minimum-maximum/ percent (%)
Age (months)	84	48-120
Gender		
Girl	8	40
Male	1	60
CP type		
Diplegic	7	35
Quadriplegic	7	35
Mix type (Spastic+dyskinetic)	6	30
Treatment		
BoNT-A + PT	7	35
BoNT-A + PT + Orthosis	13	65

BoNT-A: Botulinum toxin-A; PT: Physical theraphy; CP: Cerebral palsy.

TABLE 2: Clinical data of the patients at the pre-treatment and after treatment.

		After first injection 3rd months		
	Pre-treatment Mean±SD	Mean±SD	12th months Mean±SD	p value
MAS				
Right	2.05±0.62	1.42±0.83	1.68±0.82	**0.007**
Left	2.15±0.67	1.55±0.82	1.70±0.92	**0.005**
Knee distance test (cm)				
Flexion				
Slow	35.85±8.70	39.35±10.45	43.10±10.36	**<0.001**
Fast	34.35±9.29	37.45±8.91	40.25±9.46	**<0.001**
Extension				
Slow	30.25±6.35	31.45±8.325	35.55±9.77	**0.03**
Fast	28.40±7.33	29.80±8.75	33.20±11.15	0.06
GMFCS	**(n/%) -**	**(n/%)**	**(n/%)**	
Level 2			1/ 5	
Level 3	7 / 35	13/65	12/ 60	**0.002**
Level 4	10 / 50	5/25	6/30	
Level 5	3 / 15	2/10	1/ 5	

SD: Standard deviation; MAS: Modified asworth scale; GMFCS: Gross motor function classification system.

(p:0.002). However, in the radiological evaluation, AI and CDA measurements were not statistically significantly different at the third and twelfth months after the first injection compared to pre-treatment (p>0.05), (Table 3). But**,** a patient who received BoNT-A injections 3 times at 4 months interval, then underwent hip surgery.

DISCUSSION

Hip adductor muscle spasticity is the most important treatable biomechanical for hip subluxation or dislocation in CP patients. In a healthy individual, the hip muscle strength direction is medial-superior to the acetabulum, but in patients with adductor muscle spasticity, this direction is displaced in the lateral-superior direction, and therefore the femoral head cannot be covered completely.[17,18]

In our study, we found that there were significant changes in the clinical evaluations including between knees distance, MAS, and GMFCS scores compared to pre-treatment. While BoNT-A injection increases ambulation especially in the group of GMFCS level of 1-2-3, in the group of GMFCS level 4-5, it mostly helps to relieve pain, fit the sitting function, adapt to PT or orthosis and care of the patient (attachment of the diaper, perineal hygiene). Santos et al. showed that the life standards of CP patients who received BoNT-A injection increased more.[19] In our study, we found that the scores of GMFCS and MAS at the third and twelfth months after the injection compared with those of before BoNT-A injection were significantly improved. Other studies have shown that BoNT-A injection significantly improved MAS and GMFCS values in CP patients.[20-22] In addition to significant improvement in hip adductor spasticity, unlike previous studies, we found significant improvements in measurements of the distance between the knees after the treatment compared to before treatment both knee flexion and extension, and, both quickly and slowly.

Mirska et al. showed that BoNT-A therapy is effective for three months and its effectiveness doesn't dependent to the number of sessions, depends on the age and type of spasticity of patients.[23] Similarly, in our study we evaluated all our patients at the end of the third months then if there is need, BoNT-A theraphy was applicated. Alexander et al. reported that BoNT-A injection had an atrophic effect on muscle mass since the first application.[24] We did not encounter such a side effect in our patients, because we

TABLE 3: Comparison of radiological values before and after treatment.

	Pre-treatment Mean±SD	After first injection 3rd months Mean±SD	After treatment 12th months Mean±SD	p value
AI				
Right	23.61±5.23	23.17±5.48	24.59±5.01	0.395
Left	23.37±5.33	22.48±4.50	23.69±4.64	0.373
CDA				
Right	152.57±10.82	153.10±9.30	154.35±10.75	0.665
Left	153.13±10.12	152.81±10.56	154.18±12.05	0.796

SD: Standard deviation; AI: Acetabular index; CDA: Collo-diaphyseal angle.

did not apply very high doses. Eek et al. showed in their study that the patients who underwent BoNT-A on the lower extremity increased their plantar flexion muscle strength more than the untreated group at the end of 6 months.[25] Boyd et al. showed that CP patients with adductor muscle spasticity who received only PT and patients who applied both of orthosis and BoNT-A injection had similar effects on GMFCS score.[26] In our study, all patients received PT and BoNT-A injection together. In addition, 6 patients had used hip abductor orthosis. We could not make a comparison between the two groups because the number of patients was insufficient. We believe that prospectively planned new studies are needed on this subject.

Unlike previous studies, we followed hip dislocation radiologically by both AI and CDA. In many other studies, it is stated that AI or CDA are the methods that can be used safely in the follow-up of hip instability.[27-29] We compared the numerical values we obtained from two separate measurements with each other. Hip radiographs of patients were taken before BoNT-A injection and after third and twelfth months of BoNT-A injection. Then, AI and CDA values were calculated. In our study, no statistically significant difference was found in AI and CDA values compared to before and after BoNT-A injection. However, a patient who received BoNT injections 3 times at 4 months intervals, after one year underwent hip surgery. Based on these findings, it has been seen that BoNT-A injection did not improve our patients' radiological scores but prevented progressive hip subluxation or dislocation except for one patient. Jung et al. had examined 21 patients before and after BoNT-A for 2 years with migration index (MI) method.[30] Similarly, they had stated that BoNT-A did not correct the radiological findings but stopped progressing in hip subluxation. BoNT-A had been shown to provide hip stability for 2 years.[30] Considering that the most important causes of hip dislocation are hip spasticity, BoNT-A administration may be thought to slow down hip dislocation progression. Pidcock et al. showed that the effect of BoNT-A on MI was higher in children under 2 years old than in those over 2 years old.[31] However, in our study, we could not evaluate this because we could not administer BoNT-A to children under 2 years old. Placzek et al. performed 2-year follow-up of 5 patients who received BoNT-A, and showed a 44-51% improvement in MI at the 9th month.[32] In our study, unlike other studies, hip dislocation was evaluated radiologically with both AI and CDA.

CONCLUSION

In conclusion, based on the findings obtained from our study, we believe that consecutive BoNT-A injection may provide clinical improvement in patients with CP with spasticity in the hip adductor muscles and may prevent progression radiologically. In addition, we think that life standards of both the caregivers and the patients themselves are increased.

Limitations

The study was retrospective so we used only the data which we obtained from patient files. Also, the number of the cases were not enough. So, if we gather much more patient, we can evaluate much more data.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

REFERENCES

1. Bax M, Goldstein M, Rosenbaum P, et al; Executive committee for the definition of cerebral palsy. Proposed definition and classification of cerebral palsy, April 2005. Dev Med Child Neurol. 2005;47:571-6. [Crossref] [Pubmed]
2. Sankar C, Mundkur N. Cerebral palsy-definition, classification, etiology and early diagnosis. Indian J Pediatr. 2005;72:865-8. [Crossref] [Pubmed]
3. Serdaroğlu A, Cansu A, Ozkan S, et al. Prevalence of cerebral palsy in Turkish children between the ages of 2 and 16 years. Dev Med Child Neurol. 2006;48:413-6. [Crossref] [Pubmed]
4. Shrader MW, Wimberly L, Thompson R. Hip surveillance in children with cerebral palsy. J Am Acad Orthop Surg. 2019;27:760-8. [Crossref] [Pubmed]
5. Howard CB, McKibbin B, Williams LA, et al. Factors affecting the incidence of hip dislocation in cerebral palsy. J Bone Joint Surg Br. 1985;67(4):530-2. [Crossref] [Pubmed]
6. Lonstein JE, Beck K. Hip dislocation and subluxation in cerebral palsy. J Pediatr Orthop. 1986;6:521-6. [Crossref] [Pubmed]
7. Terjesen T. Development of the hip joints in unoperated children with cerebral palsy: a radiographic study of 76 patients. Acta Orthop. 2006;77:125-31. [Crossref] [Pubmed]
8. Ramstad K, Jahnsen R, Skjeldal OH, et al. Characteristics of recurrent musculoskeletal pain in children with cerebral palsy aged 8 to 18 years. Dev Med Child Neurol. 2011;53:1013-8. [Crossref] [Pubmed]
9. Graham HK. Painful hip dislocation in cerebral palsy. Lancet. 2002;359:907-8. [Crossref] [Pubmed]
10. Laplaza FJ, Root L, Tassanawipas A, et al. Femoral torsion and neck-shaft angles in cerebral palsy. J Pediatr Orthop. 1993;13:192-9. [Pubmed]
11. Sharrard WJ, Allen JM, Heaney SH. Surgical prophylaxis of subluxation and dislocation of the hip in cerebral palsy. J Bone Joint Surg Br. 1975;57:160-6. [Crossref] [Pubmed]
12. Tilton AH. Management of spasticity in children with cerebral palsy. Semin Pediatr Neurol. 2004;11:58-65. [Crossref] [Pubmed]
13. Koog YH, Min BI. Effects of botulinum toxin A on calf muscles in children with cerebral palsy: a systematic review. Clin Rehabil. 2010;24:685-700. [Crossref] [Pubmed]
14. Ryll U, Bastiaenen C, De Bie R, et al. Effects of leg muscle botulinum toxin A injections on walking in children with spasticity-related cerebral palsy: a systematic review. Dev Med Child Neurol. 2011;53:210-6. [Crossref] [Pubmed]
15. Pin TW, Elmasry J, Lewis J. Efficacy of botulinum toxin A in children with cerebral palsy in Gross Motor Function Classification System levels IV and V: a systematic review. Dev Med Child Neurol. 2013;55:304-13. [Crossref] [Pubmed]
16. Shrader M.W., Crea B. Hip Dysplasia in Children with Cerebral Palsy. Cerebral Palsy. 2018;27:201-8. [Crossref]
17. Kalen V, Bleck EE. Prevention of spastic paralytic dislocation of the hip. Dev Med Child Neurol. 1985;27:17-24. [Crossref] [Pubmed]
18. Miller F, Slomczykowski M, Cope R, et al. Computer modeling of the pathomechanics of spastic hip dislocation in children. J Pediatr Orthop. 1999;19:486-92. [Crossref] [Pubmed]
19. Coutinho dos Santos LH, Bufara Rodrigues DC, Simões de Assis TR, et al. Effective results with botulinum toxin in cerebral palsy. Pediatr Neurol. 2011;44:357-63. [Crossref] [Pubmed]
20. Linder M, Schindler G, Michaelis U, et al. Medium-term functional benefits in children with cerebral palsy treated with botulinum toxin type A: 1-year follow-up using gross motor function measure. Eur J Neurol. 2001;8:120-6. [Crossref] [Pubmed]
21. Mall V, Heinen F, Kirschner J, et al. Evaluation of botulinum toxin A therapy in children with adductor spasm by gross motor function measure. J Child Neurol. 2000;15:214-7. [Crossref] [Pubmed]
22. Aydil S, Akpinar FM, Akpinar E, et al. Effectiveness of multilevel botulinum toxin a ınjection with ıntegrated treatment program on spasticity reduction in non-ambulatory young children with cerebral palsy. Med Princ Pract. 2019;28:309-14. [Crossref] [Pubmed] [PMC]
23. Mirska A, Kułak W, Okurowska-Zawada B, et al. Effectiveness of multiple botulinum toxin sessions and the duration of effects in spasticity therapy in children with cerebral palsy. Childs Nerv Syst. 2019;35:141-7. [Crossref] [Pubmed] [PMC]
24. Alexander C, Elliott C, Valentine J, et al. Muscle volume alterations after first botulinum neurotoxin A treatment in children with cerebral palsy: a 6-month prospective cohort study. Dev Med Child Neurol. 2018;60:1165-71. [Crossref] [Pubmed]
25. Eek MN, Himmelmann K. No decrease in muscle strength after botulinum neurotoxin-a injection in children with cerebral palsy. Front Hum Neurosci. 2016;10:506. [Crossref] [Pubmed] [PMC]
26. Boyd RN, Dobson F, Parrott J, et al. The effect of botulinum toxin type A and a variable hip abduction orthosis on gross motor function: a randomized controlled trial. Eur J Neurol. 2001;8:109-19. [Crossref] [Pubmed]
27. Yang Y, Porter D, Zhao L, et al. How to judge pelvic malposition when assessing acetabular index in children? Three simple parameters can determine acceptability. J Orthop Surg Res. 2020;15:12. [Crossref] [Pubmed] [PMC]
28. Shore BJ, Martinkevich P, Riazi M, et al; CHOP Investigative Team. Reliability of radiographic assessments of the Hip in cerebral palsy. J Pediatr Orthop. 2019;39:e536-e541. [Crossref] [Pubmed]
29. Flynn JM, Miller F. Management of hip disorders in patients with cerebral palsy. J Am Acad Orthop Surg. 2002;10:198-209. [Crossref] [Pubmed]
30. Jung NH, Heinen F, Westhoff B, Doederlein L, Reissig A, Berweck S, Linder-Lucht M, Schandelmaier S, Mall V; German Abo study group. Hip lateralisation in children with bilateral spastic cerebral palsy treated with botulinum toxin type A: a 2-year follow-up. Neuropediatrics. 201;42:18-23. [Crossref] [Pubmed]
31. Pidcock FS, Fish DE, Johnson-Greene D, et al. Hip migration percentage in children with cerebral palsy treated with botulinum toxin type A. Arch Phys Med Rehabil. 2005;8:431-5. [Crossref] [Pubmed]
32. Placzek R, Deuretzbacher G, Meiss AL. Treatment of lateralisation and subluxation of the hip in cerebral palsy with Botulinum toxin A: preliminary results based on the analysis of migration percentage data. Neuropediatrics. 2004;35:6-9. [Crossref] [Pubmed]