Eurasian Journal of Analytical Chemistry
ISSN: 1306-3057

EFFICACY OF SINGLE STAGE MULTILEVEL SOFT TISSUE RELEASE BY PERCUTANEOUS NEEDLE TECHNIQUE FOR SPASTIC CONTRACTURES OF LOWER LIMBS IN CEREBRAL PALSY

Abdulmonem M. Alsiddiky, SSC-Orth*, Khalid A. Bakarman, ABOS, Kholoud O. Alzain, SSC-Orth, Zulqurnain Rafiq, FCP, Ibrahim Alshaygy, SSC-Orth, Fahad Alhuzaimi, SSC-Orth, Waleed Awwad, FRCSC, Abdel Rahman M. Zamzam, MSc and Muhammed Asif, FCPS

*Associate Professor and Consultant Orthopaedic Surgeon Department of Orthopaedics (49) Director of Research Chair of Spinal Deformities College of Medicine, King Saud University PO Box 7805, Riyadh 11472, Saudi Arabia.

Received 19 January 2018 ▪ Revised 09 February 2018 ▪ Accepted 2 March 2018

ABSTRACT

Background: *Single-stage multi-level percutaneous tenotomy and tendon lengthening using scalpel is a frequently used procedure in lower limbs for spastic cerebral palsy (CP). This study was performed to assess the outcome of single-stage multilevel percutaneous needle tenotomy and tendon lengthening among CP patients. Methods: A retrospective study was performed to analyze the data of all patients who were known to have Cerebral palsy and underwent percutaneous needle muscle-tendon surgery at authors' institute during the period between January 2005 and January 2012. We excluded patients with extrapyramidal system involvement, those requiring bony correction or taking anti-spasticity therapy and cases with incomplete information. All patients were followed up regularly for at least 4 years. Results: There were 174 patients, 98 males (56.3%) and 76 females (43.7%). The mean age at time of surgery was 7.4 years ± 3.1 (range, 2 to 13). There was no major complications. Minor bleedings were reported in 39 patients (22.4%). 97 patients had hip affection. Recurrence of hip adduction deformity occurred in 19 patients (19.6%). Fixed flexion deformity of the knee was managed in 152 patients. Recurrence of deformity occurred in 47 knees (16.7%). Hyperextension or recurvatum deformity occurred in 14 knees (5%). There was equinus deformity of the ankle in 135 patients. Recurrence of equinus occurred in 33 ankles (13%). The postoperative improvement of hip, knee and ankle motions was found significant statistically ($p< 0.0001$) at final follow up. Conclusion: Percutaneous needle tenotomy and tendon lengthening proved to be safe and effective minimally invasive surgical approach for spastic contractures in the lower limbs. Our results support using this technique when performing single stage multilevel surgical releases in CP patients to achieve improvement in function and hygiene.*

KEYWORDS: *percutaneous, needle, tenotomy, spasticity, cerebral palsy.*

INTRODUCTION

Cerebral palsy (CP) is frequently associated with joint deformities due to contractures particularly in the lower limbs. These include hip adduction deformity[1], knee flexion deformity that related to hamstring spasticity[2], and equinus deformity of the ankle.[3] Lower limb deformities in CP are usually associated with difficulty in maintaining hygiene, posture and nursing care.[4] Surgical approaches involving soft tissue release or bone surgery are usually effective treatment for contractures.[1,5] A number of surgical methods have been described for soft tissue release, varying from aponeurotic lengthening to Z-lengthening to tenotomy.[6,7] Despite early postoperative favorable outcome after soft tissue release, recurrence overcorrection have been reported in many cases.[8]

Percutaneous needle cutting technique using the bevel of a large needle to section tendinous or ligamentous structures has been used in patients with congenital talipes equinovarus, chronic tennis elbow, carpal tunnel syndrome and trigger finger.[5,9] Although this technique has been used with favorable outcome for Achilles tendon lengthening or tenotomy in congenital talipes equinovarus with an effectiveness similar to open surgery in 80% of cases, there are however limited data on efficacy of using this technique in muscle contractures[10] Moreover, the efficacy of percutaneous needle tenotomy for other tendons remains to be assessed. Application of percutaneous needle technique on cadavers has recently been shown to be an effective or method for sectioning the desired tendons with negligible injuries to the adjacent tissues.[5]

The purpose of this retrospective study was to evaluate the effectiveness and safety of single stage multi-level percutaneous needle tenotomy and/or tendon lengthening in children with CP.

MATERIAL AND METHODS

A retrospective study was performed to analyze the data of all patients who were known to have CP and underwent percutaneous needle tenotomy or tendon lengthening at authors' institute during the period between January 2005 and January 2012. Patients with extrapyramidal system involvement, those requiring bony correction for deformities and patient on continuous anti-spasticity therapy and cases with incomplete information were excluded from the study.

The collected data for each patient included the demographic data, the physiological and anatomical types of the disease, the ambulatory status of the patient and any previous surgery that was related to the same condition. The data for pre-operative assessments were also collected for hips, knees and ankles of both sides. For the hip affection, the range of abduction and the presence of fixed flexion deformity were recorded. The range of knee flexion and extension and the degree of popliteal angle were also recorded for affected knees. Ankle dorsiflexion range and any fixed deformity were recorded for affected ankles. The gait of ambulatory patients and the radiological findings, if applicable, were recorded as well. The surgical data included age at time of surgery, operative time, the muscles that were released during surgery and the type of cast applied after surgery. Duration of cast, the use of orthosis and the details of applied physical therapy were recorded. Finally, we collected the data of immediate post-operative assessment and that after cast removal and at final follow up.

All patients in the study where admitted one day prior to surgery for general assessment and to be assessed by the anesthetists, then most of them went home and came back in the early morning of the day of surgery. All patients underwent percutaneous release of one or more joints of the lower limbs under general anesthesia by using 18G injection needle. The technique was applied for adductor tenotomy to correct hip adduction deformity (duration: 2-4 minutes for each hip), hamstring release for knee flexion contractures (duration: 5-7 minutes for each knee) and Achilles tendon lengthening for ankle equinus (duration: 8-10 minutes for each ankle). After achieving correction of the addressed deformities and reaching an accepted range of motion, the sites of needle entries were covered by band aid.

A long leg cast was applied for 3 weeks after correction of knee flexion deformity with the knee in full extension. If correction of ankle equinus was included then the cast was maintained for 6 weeks with the ankle in 10 degrees of dorsiflexion. If correction of hip adduction deformity was included then a broom stick was applied for 3 weeks to bilateral long leg casts to keep both hips in maximum abduction. Patients were discharged in the same day of surgery except if there was medical reason that deserved observation or if the child had severe pain and needed strong analgesia. After discontinuing the cast; physiotherapy was commenced for all patients in the form of muscle stretching exercise, maintaining range of motion and walking exercise if applicable. All patients who had correction of ankle or knee deformities used an ankle-foot orthosis or a knee-ankle-foot orthosis for an additional four weeks and as night splint for different

duration according to situation of each patient. All patients were followed up regularly for at least four years.

Statistical analysis was performed for the data of hip, knee and ankle joints separately by using SPSS software version 23 (SPSS Inc., Chicago, Illinois). A paired Students *t*-test was used to assess pre- and post-operative differences for each joint. A further analysis was done using a generalized linear regression model. All analyses were conducted at a significance level of 0.05.

RESULTS

There were 174 patients, 98 males (56.3%) and 76 females (43.7%). The mean age of the patients at time of surgery was 7.4 years ± 3.1 (range, 2 to 13). 112 patients (64.4%) had spastic diplegia, 34 (19.5%) had quadriplegia, 23 (13.2%) were hemiplegic and 5 patients (2.9%) had triplegia. Preoperative assessment revealed that 34 patients (19.5%) lacked ambulation while 49 patients (28.2%) could ambulate with the use of a gait support and 91 (52.3%) were independently walkers. The mean operative time, without the duration of cast application, for all patients was 19.29 minutes ± 7. 6. Table (1) showed distribution of all patients according to the affection of the joints of both lower limbs.

There was no major complications. No patient showed nerve injury. Minor bleedings were reported in 39 patients (22.4%), 17 (8.8%) at the site of adductor tenotomy and 22 (8.7%) at the site of Achilles tendon lengthening. There was no bleeding at the site of hamstring tenotomy. All bleedings were controlled by local pressure only without late sequelae. Loss of correction was considered a complication if deformity recurred and deserved revision surgery.

Ninety seven patients in the current study had hip affection. 55 were males (56.7%) and 42 females (43.3%). Their mean age was 6.9 years ± 3.17. Out of them 70 children (72.2%) were walkers before surgery. 81 children (83.5%) were on regular physical therapy, 30 children (30.9%) used splint or orthotics, 14 (14.4%) had received Botox injection, and 19 (19.6%) had previous surgical intervention but not by the same technique. Recurrence of deformity that needs revision surgery occurred in 19 patients (19.6%). A paired t-test was run on a sample of 194 hips. The mean range of hip abduction preoperatively and after cast removal were

26.1 ± 9.2 and 47.8 ± 10.4 degrees respectively (Figure, 1). This increase of hip abduction was found statistically significant, $p< 0.0001$ (95% CI, 18.84 to 22.86). There was no significant differences in the mean range of hip abduction immediately after surgery, at time of cast removal and at final follow up. A further analysis was done using a generalized linear regression model with all other variables as covariates. Only diplegia had a significant association with the difference in hip range of abduction ($p< 0.05$).

Fixed flexion deformity of the knee was managed in 152 patients. 87 were males (57.2%) and 65 females (42.8%). Their mean age was 8.08 years ± 4.74. 123 children (80.9%) were walkers before surgery with or without support. 138 children (90.8%) were on regular physical therapy, 59 children (38.8%) were using splint or orthotics, 32 (21.1%) had received Botox injection, and 56 (36.8%) had at least one previous surgery. Recurrence of deformity occurred in 47 knees (16.7%) for 29 patients. Hyperextension or recurvatum deformity occurred in 14 knees (5%), all of them improved with physical therapy and splints. A paired t-test was run on a sample of 282 knees. The mean range of popliteal angle preoperatively and after cast removal were 46.99 ± 36.38 and 10.88 ± 7.01 degrees respectively (Figure, 2), a decrease that was found significant statistically, $p< 0.0001$ (95% CI, -41.5 to -31.4). There was significant increase in the mean popliteal angle from the time of cast removal (10.88 ± 7.01 degrees) to the time of final follow up (19.76 ± 8.09 degrees), $p<0.0001$ (95% CI, 7.68 to 10.04). However, the decrease in popliteal angle between preoperative assessment and at final follow up still significant statistically ($p< 0.0001$). A further analysis was done using a generalized linear regression model with all other variables as covariates. Hemiplegia was the only variable that had a significant association with the decrease in popliteal angle ($p< 0.05$).

There was equinus deformity of the ankle in 135 patients. 72 were males (53.3%) and 63 females (46.7%).

Their mean age was 6.61 years ± 2.96. 105 children (77.8%) were walkers before surgery with or without support. 111 children (82.2%) were on regular physical therapy, 48 children (35.6%) were using splint or orthotics, 28 (20.7%) had received Botox injection, and 31 (23%) had previous correction by different technique. Recurrence of equinus occurred in 33 ankles (13%). No calcaneal deformity was noticed in our patients. 27 Achilles tendons (10.6%) sustained inadvertent complete tenotomy, none of the patients who had this incident complained any disability postoperatively and they are indistinguishable from other patients at final follow up. A paired t-test was run on a sample of 254 ankles. The mean range of ankle dorsiflexion during knee extension preoperatively and after cast removal were -7.09 ± 7.73 and 14.77

± 8.74 degrees respectively (Figure, 3). The improvement of ankle dorsiflexion with knee extension was found significant statistically, p< 0.0001 (95% CI, 20.3 to 23.5). Again, the mean range of ankle dorsiflexion during knee flexion was calculated preoperatively and after cast removal. They were -6.03 ± 6.99 and 14.77 ± 8.74 degrees respectively. The improvement of ankle dorsiflexion with the flexed knee was found significant statistically, p< 0.0001 (95% CI, 19.46 to 22.15). There was significant decrease in the mean range of ankle dorsiflexion from the time of cast removal (14.77 ± 8.74 degrees) to the time of final follow up (10.11 ± 7.07 degrees), p<0.0001 (95% CI, 5.57 to -3.73). However, the increase in ankle dorsiflexion between preoperative assessment and at final follow up still significant statistically (p< 0.0001). The primary analysis was performed using a generalized linear regression model with covariates gender and age. Female gender was found to have significant association with deformity relapse at the final follow up compared with the correction after cast removal. A further analysis was done using a generalized linear regression model with all other variables as covariates. Our results showed no significant association between all variables and the increase of ankle range of dorsiflexion (p> 0.05).

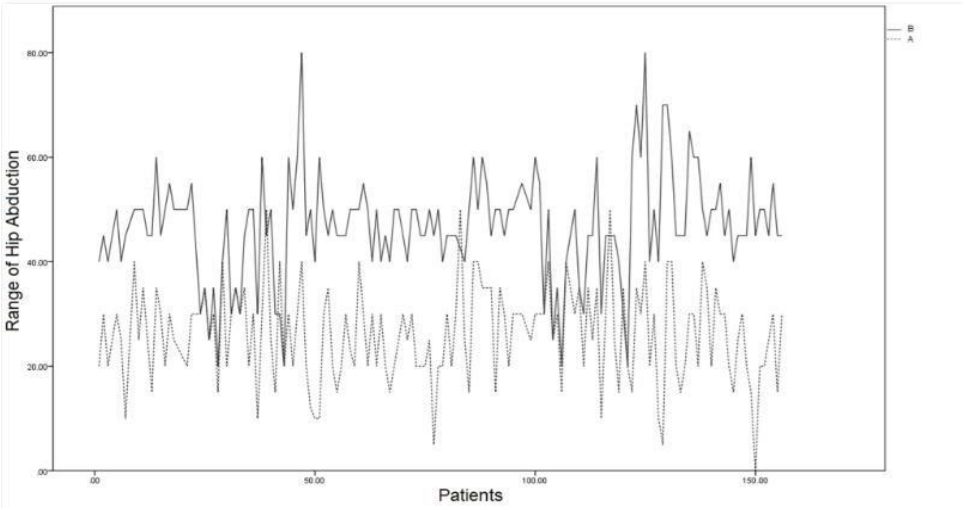

Fig 1: Line graph representing the change in range of hip abduction per patient over twice intervals. (A: preoperative, B: after cast removal)

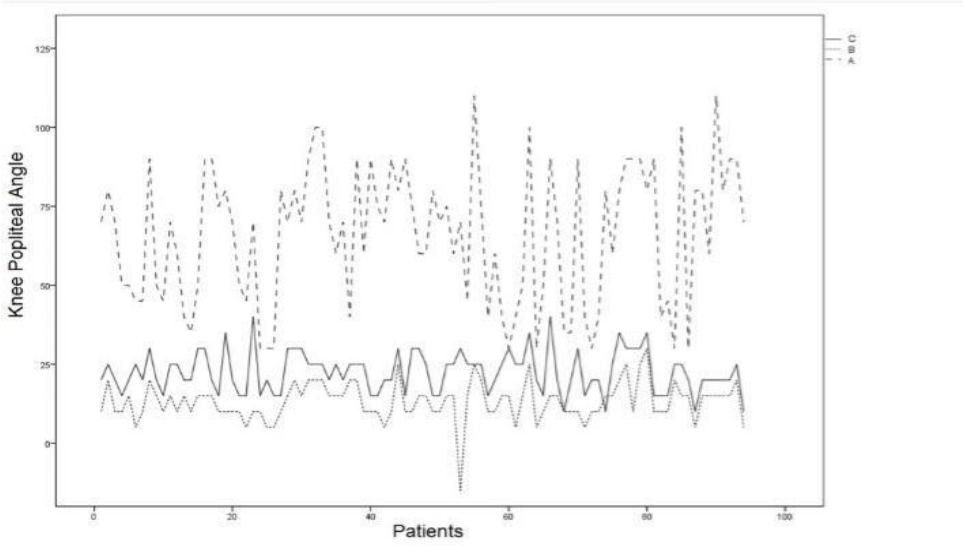

Fig 2: Line graph representing the change in knee popliteal angle per patient over triple intervals. (A: preoperative, B: after cast removal, C: at final follow up)

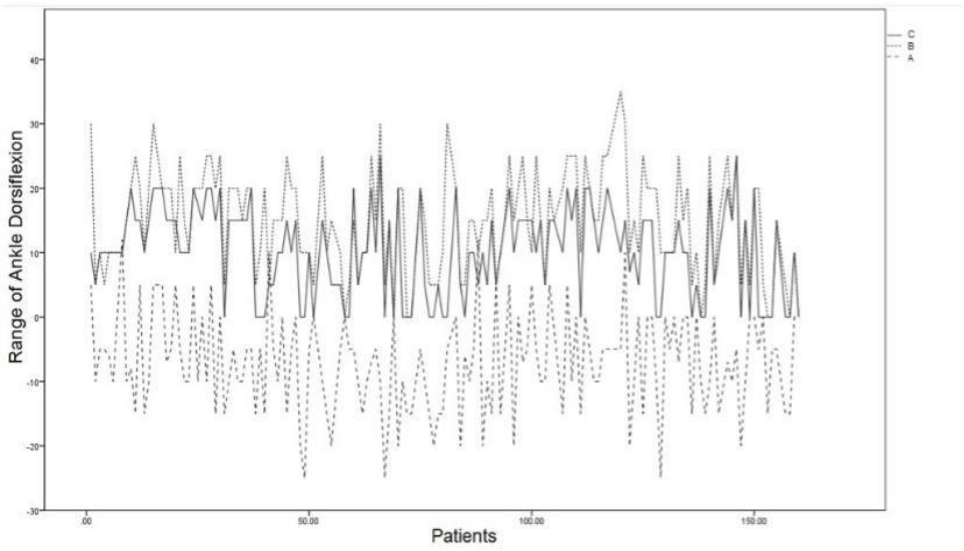

Fig 3: Line graph representing the change in range of ankle dorsiflexion per patient over triple intervals. (A: preoperative, B: after cast removal, C: at final follow up)

Table 1: Distribution of all patients according to joints' affections of both lower limbs.

	Unilateral	**Bilateral**
Hip	--	--
Knee	10	18
Ankle	4	14
Hip + Knee	--	11
Hip + Ankle	--	4
Knee + Ankle	12	19
Hip + Knee + Ankle	--	82
Total	26	148

DISCUSSION

Decision making in spastic patients with CP is based on observing patients' gait, clinical examination, measurement of range of motion and spasticity, and can be augmented by the use of computer-based gait analysis.[11,12] The treatment strategy of CP should be customized according to the patient's affection. The main goal of orthopedic treatment may vary from maintaining hygiene, achieving independent and balanced sitting, maintaining mobility and independent ambulation, to improving the gait and decreasing energy consumption during walking.[4]

A combined program of multilevel surgical release, orthotic support and rehabilitation was suggested for pain relief and improvements in dynamic hip, knee and ankle function.[13] Currently, percutaneous simultaneous release of all contractures in the hip, knee and ankle has been recommended for maximum benefit to the patients with CP in terms of more balanced posture and functional gain.[14,15] Although, there are doubts regarding the age, indications for the surgical procedures and the muscles involved[16], the result of our study suggested that soft-tissue surgery for CP patients should be performed as early as possible independent of age, sex, walking condition, and type of spasticity because of the benefits relating to walking, hygiene, pain relief and prevention of hip subluxation.

In children with spastic CP adductor muscles exert forces that are too strong, particularly the adductor longus and the gracilis. The resulting muscle imbalance causes abnormal position of the hip and the child suffers painful seating, gait abnormality and difficult personal hygiene.[15,17,18] Although many conservative treatment modalities exist, adductor tenotomy is often required to prevent subluxation and dislocation of the spastic hips and possibly the need for future bony procedure.[15,16]

Our results agree with previous studies. [7,16,18,19] stating that bilateral percutaneous adductor release is fast, simple, safe and effective treatment when performed correctly in patients with CP with adductor contractures. And, disagree with Hachache et al [15] that percutaneous adductor tenotomy is not as safe as open procedure mainly because of the increased risk of bleeding. Previous studies stated that final outcome following adductor releases for spastic hip is related to age at surgery, degree of the deformity, hip migration percentage, surgical technique and the type of neurological involvement[16,17] However, the current study showed association of satisfactory results with only spastic diplegic patients. The recurrence rate of adductor contractures that required further surgical release in the present study (19.6%) is less than previously reported rate of 34.6% [18] The findings of our study showed significant improvement in passive hip motion, which indicates that adequate release of adductors could be achieved by percutaneous needle tenotomy technique.

Flexion deformity related to hamstring spasticity is a common knee deformity in children with CP. Popliteal angle measurement is widely used for clinical assessment of hamstring spasticity and has good intraobserver reliability. Optional surgical procedures include percutaneous tenotomy of the semimembranosus, semitendinosus, and biceps femoris muscles [2,6] The final outcome after hamstring tenotomy in the present study is comparable with previous studies[2,8,20] Damron et al[8] stated that severity of the contracture had positive relationship with the magnitude of correction, while there is no relationship between the results and disease classification or initial age. Our results agree with Sarikaya et al [2] that age and severity of the deformity have no significant effect on the amount of popliteal angle correction. However, our results showed significant association of hemiplegic patients with the decrease in popliteal angle.

Knee recurvatum of up to 10 degrees has been reported as a potential negative effect at a rate of up to 30% after hamstring tenotomy[2,6] The incidence of recurvatum in the present study was 5%, nevertheless we agree with Damron et al[8] that the severity of recurvatum decreases steadily with time. Recurrence of knee flexion deformity is another common complication after hamstring tenotomy with rates ranged between 4 to 40% in the literature.[2,8] Its incidence in our study (16.7%) fell within this range.

Equinus deformity is frequently seen in ambulatory children with CP. Surgical correction of persistent deformity is indicated to improve gait or to enable the use of orthoses [3,12,21] Various techniques for percutaneous Achilles tendon lengthening were described[3,22] Our results agree with previous reports[2123] stating that percutaneous techniques are not associated with a risk of serious complications and their advantages include short operative time, negligible scarring, early weight bearing, low incidence of recurrence or developing calcaneal deformity.

Remarkable improvement in ankle dorsiflexion both in knee extension and 90° flexion was observed in the present study. We agree with previous studies [6,8] stating that increased knee extension coupled with improvement in foot dorsiflexion is considered the key factor for gait improvement after surgical release in CP children.

Disadvantages or complications of the percutaneous techniques include incidental complete tenotomy of the Achilles tendon, overcorrection which may result in weakness of the triceps sure muscle that leads consequently to calcaneal gait and undercorrection or recurrence of equinus. Other complications include false aneurysm caused by a lesion of the posterior tibial artery, serious bleeding due to peroneal artery or saphenous vein injury, sural neuritis, nerve entrapment or neuroma, hematoma, infection and adhesions[3,10,22-26] Among our patients we noticed only incidental complete tenotomy, recurrence of equinus and minor bleeding. Our findings agree with Berg [27] that with time the patients who had inadvertent Achilles tenotomy became indistinguishable from those in whom tendon continuity was maintained. The rate of recurrence in our series is comparable to the reported rates (9.1-43.4%) in the literature.[3,21,23,24]

We agree with Zorer et al[4] that surgery for spastic CP can be most beneficial when all contractures of the hip, knee, and ankle have been corrected simultaneously. Single-stage multilevel percutaneous tenotomy has been shown definite advantages over staged interventions and is usually associated with gait improvement, less morbidity and better rehabilitation. The preoperative plan should be reconsidered during surgery and when intervention of one level is finished, assessment should be repeated before proceeding to another level[4,7,14]

Authors of previous studies have stressed on performing surgical releases by minimally invasive techniques as much as possible.[4,7] In exploring various methods for performing the tenotomy, Minkowitz et al[28] have found the use of a large-gauge needle to be simple, costeffective, and readily available. Data regarding percutaneous needle technique is insufficient however the use of needle for the division of retinacular, ligamentous or tendinous structures have been reported with negligible complications or failures.[5,9] The lack of serious complications in the present study using percutaneous needle technique highlights its safety as minimally invasive surgical approach. Furthermore, the authors agree with Chesnel et al[5] who demonstrated that the majority of tenotomies, carried out by operators who were new to the technique, were successful. However, training is essential before beginning to practice needle technique for tenotomies or tendon lengthening for CP patients and consequently for other conditions either in outpatient or in the operating theatre.

A weakness point of our study besides being a retrospective one, is the lack of support of the findings by pre- and post-operative gait analysis. The advantages of gait analysis are well documented. However, that doesn't mean that achieving successful results by surgical treatment of CP patients is not possible without gait analysis.

In conclusion, percutaneous needle tenotomy and tendon lengthening performed in the present study proved to be safe and effective minimally invasive surgical approach for spastic contractures in the lower limbs. We recommend using this technique when performing single stage multilevel surgical releases in CP patients to achieve improvement in function and hygiene.

ACKNOWLEDGMENT

The authors thank Prof. Mohamed Zamzam MD, for his help during preparation of the manuscript.

REFERENCES

[1]. Chang FM, Ma J, Pan Z, Ingram JD, Novais EN. Acetabular Remodeling After a Varus Derotational Osteotomy in Children With Cerebral Palsy. J Pediatr Orthop, Mar, 2016; 36(2): 198-204. doi: 10.1097/BPO.0000000000000418.

[2]. Sarıkaya İA, İnan M, Şeker A. Improvement of popliteal angle with semitendinosus or gastrocnemius tenotomies in children with cerebral palsy. Acta Orthop Traumatol Turc, 2015; 49(1): 516. doi: 10.3944/AOTT.2015.14.0078.

[3]. Saraph V, Zwick EB, Uitz C, Linhart W, Steinwender G. The Baumann procedure for fixed contracture of the gastrosoleus in cerebral palsy.

Evaluation of function of the ankle after multilevel surgery. J Bone Joint Surg Br., May, 2000; 82(4): 535-40.

[4]. Zorer G, Doğrul C, Albayrak M, Bagatur AE. The results of single-stage multilevel muscle-tendon surgery in the lower extremities of patients with spastic cerebral palsy. Acta Orthop Traumatol Turc, 2004; 38(5): 317-25.

[5]. Chesnel C, Genêt F, Almangour W, Denormandie P, Parratte B, Schnitzler A.

Effectiveness and Complications of Percutaneous Needle Tenotomy with a Large Needle for Muscle Contractures: A Cadaver Study. PLoS One., Dec, 2015; 1; 10(12): e0143495. doi: 10.1371/journal.pone.0143495. eCollection, 2015.

[6]. Gordon AB, Baird GO, McMulkin ML, Caskey PM, Ferguson RL. Gait Analysis Outcomes of Percutaneous Medial Hamstring Tenotomies in Children with Cerebral Palsy. J Pediatr Orthop, Apr-

May, 2008; 28(3): 324-9. doi:10.1097/BPO.0b013e318168d1c0.

[7]. Thompson N, Stebbins J, Seniorou M, Wainwright AM, Newham DJ, Theologis TN. The use of minimally invasive techniques in multi-level surgery for children with cerebral palsy. J Bone Joint Surg Br, Oct, 2010; 92(10): 1442-8. doi: 10.1302/0301620X.92B10.24307.

[8]. Damron T, Breed AL, Roecker E. Hamstring tenotomies in cerebral palsy: long-term retrospective analysis. J Pediatr Orthop, Jul-Aug, 1991; 11(4): 514-9.

[9]. Hopkins J, Sampson M. Percutaneous tenotomy: Development of a novel, percutaneous, ultrasoundguided needle-cutting technique for division of tendons and other connective tissue structures. J Med Imaging Radiat Oncol, 2014; 58(3): 327-30. doi: 10.1111/1754-9485.12113.

[10]. Bergerault F, Fournier J, Bonnard C. Idiopathic congenital clubfoot: Initial treatment. Orthop Traumatol Surg Res. Orthop Traumatol Surg Res., Feb, 2013; 99(1): S150-9. doi: 10.1016/j.otsr.2012.11.001. Review.

[11]. Aiona MD, Sussman MD. Treatment of spastic diplegia in patients with cerebral palsy: Part II. J Pediatr Orthop B., May, 2004; 13(3): S13-38. Review.

[12]. Høiness PR, Capjon H, Lofterød B. Pain and rehabilitation problems after single-event multilevel surgery including bony foot surgery in cerebral palsy. A series of 7 children. Acta Orthop, Dec, 2014; 85(6): 646-51. doi: 10.3109/17453674.2014.960141.

[13]. Rodda JM, Graham HK, Nattrass GR, Galea MP, Baker R, Wolfe R. Correction of severe crouch gait in patients with spastic diplegia with use of multilevel orthopaedic surgery. J Bone Joint Surg Am. Dec, 2006; 88(12): 2653-64.

[14]. Saraph V, Zwick EB, Zwick G, Steinwender C, Steinwender G, Linhart W. Multilevel surgery in spastic diplegia: evaluation by physical examination and gait analysis in 25 children. J Pediatr Orthop, Mar-Apr, 2002; 22(2):150-7.

[15]. Hachache B, Eid T, Ghosn E, Sebaaly A, Kharrat K, Ghanem I. Is percutaneous proximal gracilis tenotomy as effective and safe as the open procedure? J Child Orthop, Dec, 2015; 9(6): 477-81. doi: 10.1007/s11832-015-0699-z.

[16]. Sahu RL. Percutaneous Adductor Release in Nonambulant Children with Cerebral Palsy. JNMA J Nepal Med Assoc., Jan-Mar, 2014; 52(193): 702-6.

[17]. Bishay SN. Short-term results of musculotendinous release for paralytic hip subluxation in children with spastic cerebral palsy. Ann R Coll Surg Engl, Mar, 2008; 90(2): 127-32. doi: 10.1308/003588408X261555.

[18]. Terjesen T, Lie GD, Hyldmo AA, Knaus A. Adductor tenotomy in spastic cerebral palsy. A longterm follow-up study of 78 patients. Acta Orthop, Feb, 2005; 76(1): 128-37.

[19]. El Hage S, Rachkidi R, Noun Z, Haidar R, Dagher F, Kharrat K, Ghanem I. Is percutaneous adductor tenotomy as effective and safe as the open procedure? J Pediatr Orthop, Jul-Aug, 2010; 30(5): 485-8. doi: 10.1097/BPO.0b013e3181df619d.

[20]. Jones S, Al Hussainy HA, Ali F, Garcia J, Fernandes JA, Davies AG. Distal hamstring lengthening in cerebral palsy: the influence of the proximal aponeurotic band of the semimembranosus. J Pediatr Orthop B. 2006 Mar;n 15(2): 104-8.

[21]. Krupiński M, Borowski A, Synder M. Long Term Follow-up of Subcutaneous Achilles Tendon Lengthening in the Treatment of Spastic Equinus Foot in Patients with Cerebral Palsy. Ortop Traumatol Rehabil, Mar-Apr, 2015; 17(2): 155-61. doi: 10.5604/15093492.1157092.

[22]. Haro AA 3rd, DiDomenico LA. Frontal planeguided percutaneous tendo Achilles' lengthening. J Foot Ankle Surg. 2007 Jan-Feb; 46(1): 55-61.

[23]. Firth GB, Passmore E, Sangeux M, Thomason P, Rodda J, Donath S, Selber P, Graham HK.

Multilevel surgery for equinus gait in children with spastic diplegic cerebral palsy: medium-term followup with gait analysis. J Bone Joint Surg Am., May 15, 2013; 95(10): 931-8. doi: 10.2106/JBJS.K.01542.

[24]. Chung CY, Sung KH, Lee KM, Lee SY, Choi IH, Cho TJ, Yoo WJ, Park MS. Recurrence of equinus foot deformity after tendo-achilles lengthening in patients with cerebral palsy. J Pediatr Orthop, Jun, 2015; 35(4): 419-25. doi: 10.1097/BPO.0000000000000278.

[25]. Mulier T, Molenaers G, Fabry G. A false aneurysm complicating a subcutaneous Achilles tendon lengthening. J Pediatr Orthop B, 1995; 4(1): 114-5.

[26]. Dobbs MB, Gordon JE, Walton T, Schoenecker PL. Bleeding complications following percutaneous tendoachilles tenotomy in the treatment of clubfoot deformity. J Pediatr Orthop, Jul-Aug, 2004; 24(4): 353-7.

[27]. Berg EE. Percutaneous Achilles tendon lengthening complicated by inadvertent tenotomy. J Pediatr Orthop., May-Jun; 1992; 12(3): 341-3.

[28]. Minkowitz B, Finkelstein BI, Bleicher M. Percutaneous tendo-Achilles lengthening with a large-gauge needle: a modification of the Ponseti technique for correction of idiopathic clubfoot. J Foot Ankle Surg., Jul-Aug, 2004; 43(4): 263-5.