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Review

Management issues of congenital talipes equinovarus in the neonatal intensive care unit: A systematic review

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ABSTRACT

Background: The Ponseti method is the standard of care for managing idiopathic congenital talipes equinovarus (clubfoot) in the outpatient setting, but there are no clinical guidelines for inpatient treatment. Children in the neonatal intensive care unit (NICU) with clubfoot often delay treatment initiation due to medical reasons.
Methods: We systematically reviewed literature related to the treatment of clubfoot in the NICU, non-idiopathic clubfoot, and older infants, as well as barriers to care.
Results: In a mixed NICU population of syndromic and idiopathic clubfoot, the Ponseti method has good functional outcomes with minimal interference with medical management. The Ponseti method has good functional outcomes with reduced need for extensive surgical procedures in non-idiopathic clubfoot and idiopathic clubfoot with delayed presentation (under one year of age).
Conclusions: It is possible to begin Ponseti treatment in the NICU without compromising medical management. It is not clear if this confers an advantage over waiting for outpatient casting.

Contents

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1. Introduction

Clubfoot is one of the most common orthopedic anomalies present at birth, in which the ankle is in equinus, the hindfoot is in varus, and forefoot is adducted. It occurs in 1–2 infants per 1000 live births and is twice as common in males. Clubfoot is bilateral in 30–50% of children. Presentation varies from mild postural forms to severe rigid deformities [1]. Clubfoot is typically idiopathic but can present in conjunction with congenital syndromes such as arthrogryposis, myelomeningocele, and amniotic band syndrome [2].

The Ponseti method is the global standard for treating idiopathic clubfoot [3,4]. While the Ponseti method has been studied extensively in the outpatient setting, there is little data on its use in the neonatal intensive care unit (NICU) [5]. There are no clinical guidelines for managing clubfoot in NICU patients with complex medical needs. These children typically start clubfoot treatment at a later age, often after discharge [6]. Clubfoot in NICU patients can be idiopathic, syndromic, or neuromuscular in origin, which makes it challenging to study. There is little work that directly addresses inpatient management of clubfoot and the effect of treatment in this specific population [5].

2. Methods

This is a systematic review of clubfoot treatment in the NICU using PRISMA guidelines. We conducted a search using medical subject headings (MeSH) terms 'clubfoot or congenital talipes equinovarus,' 'Ponseti treatment/method,' 'intensive care unit, neonatal,' and 'treatment outcomes/results.' This search yielded one unique result. The search was repeated replacing 'intensive care unit, neonatal' with 'inpatients' which yielded no results. The search was then broadened by removing both 'intensive care unit, neonatal' and 'inpatients' (Fig. 1). This yielded 548 results on Cochrane Library, CINAHL EBSCOhost, Google Scholar, and PubMed. The titles, abstracts, and full texts to determine relevance were reviewed. We included reviews, randomized control trials, comparative studies, and case series written in English that discuss outcomes and management of NICU patients, non-idiopathic clubfoot, and older infants under one year of age. Abstract-only publications were excluded. The references of selected articles to identify additional relevant studies were reviewed. Of the relevant citations in the English literature as of February 2020, 35 articles met our inclusion criteria and are discussed.

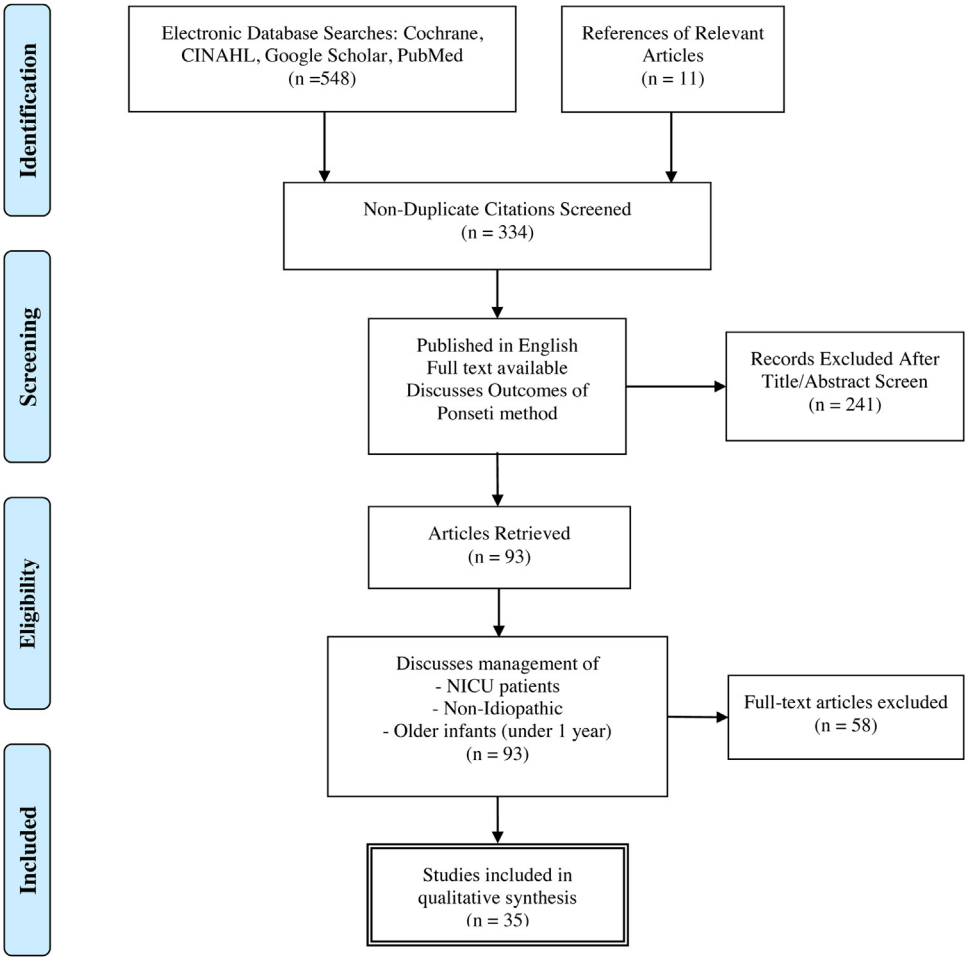

Figure 1. Methods of Systematic Review of Clubfoot Management in the NICU. This diagram outlines the search and selection process applied in our systematic review [54].

3. Results

3.1. Clubfoot treatment

3.1.1. Ponseti method

The Ponseti method is the standard of care for idiopathic clubfoot due to its high initial correction rate and excellent outcomes in long-term follow-up [7]. The clubfoot is gradually corrected by weekly manipulation and above-the-knee cast application usually beginning in the first month of life [4]. Cavus is corrected first, followed by adductus and varus, then equinus. Most clubfeet achieve correction after 4–6 casts [1,7,8]. An accelerated schedule with casts applied 3 times per week has been shown to achieve the same level of correction in an average of 16 days [1,7,8]. A percutaneous Achilles tenotomy is needed to achieve full correction of equinus in over half of clubfeet [1]. Feet not corrected by casting and tenotomy require additional soft tissue releases in the foot and ankle. To maintain correction, children with clubfeet wear a "boots and bar" abduction brace on a 23-hour wear schedule for three months or until they begin to stand, and then during nights and naps until age four [1,2,7,9]. Relapse in idiopathic clubfoot is generally attributable to brace noncompliance [1,7,10]. Relapses are treated with a second round of casting and/or surgical correction [1,7,11].

An initial correction rate of 90% has been reported in idiopathic clubfoot treated prior to one year of age with relapse in 4–27% [1,4,10,12–16]. The Ponseti method has been very effective for outpatient treatment of idiopathic clubfoot, but more work is needed on use in atypical populations [1].

3.1.2. Surgical

Historically, clubfoot was managed with surgical release of any number of the posterior, posteromedial, or posterolateral soft tissue structures in the foot and ankle [3,17]. Correction was completed prior to walking age when the foot was deemed large enough. The procedure was preceded by stretching and application of below-the-knee casts [18]. Surgical management has an initial correction rate of 70–90% [7,17]. There are similar rates of relapse between clubfeet treated surgically and with the Ponseti method, but initial Ponseti treatment leads to significantly fewer and less extensive revision surgeries [3,18–20]. Long-term outcomes of surgically-corrected clubfoot are challenged by overcorrection, stiffness, and pain later in life [3,7,17]. Those treated with the Ponseti method exhibit significantly greater range of motion of the ankle joint, greater strength, lower incidence of osteoarthritis, and higher self-reported physical function and quality of life compared to those managed surgically [21,22].

3.2. Measurement of treatment outcomes

Clubfoot outcomes are described inconsistently throughout the literature. Some studies rely on validated scoring systems to assess foot morphology and function. Scores are compared at initial presentation and follow-up to measure treatment effectiveness [23]. The Pirani scoring system characterizes clubfoot deformities based on hindfoot and midfoot morphology [24,25]. There is a positive non-linear relationship between the initial score and number of casts required for correction [24–26]. The Dimeglio scoring system assesses mobility and morphology [27]. Lower initial scores are associated with plantigrade feet following casting and tenotomy [25]. Other validated scoring systems assess morphology, range of motion, function, and patient satisfaction [9,17,22].

Many studies provide their own definition of a "corrected" foot. A corrected idiopathic clubfoot is considered to be pain-free and plantigrade with no residual forefoot adductus, cavus, or hindfoot varus [11,12,14,28–30]. In non-idiopathic clubfoot, the definition of "corrected" is limited to pain-free, plantigrade and the ability to fit into orthotics or walk independently [5,16,31–35].

Some studies measure outcomes in terms of relapse [3,18,32,36]. Relapse is defined as recurrence of deformity after initial correction that requires additional casting and/or surgery [3,11,14,18,30,36]. Number of casts and need for tenotomy are also typically reported [1]. Inconsistent outcomes measures complicate comparison across studies.

3.3. Management of clubfoot in the NICU

The primary focus of treating NICU patients is addressing their serious medical needs, although other conditions (like clubfoot) may be present during the acute phase of care [6]. There is limited evidence for management of orthopedic conditions in the NICU [5,6].

Lebel et al. examined the use of Ponseti casting in a mixed population of 20 children with idiopathic and non-idiopathic clubfoot (30 feet) [5]. Ten children were diagnosed with an identifiable syndrome [5]. Treatment began as soon as medically possible, which was in the first week of life for 80%. Three of 75 casts (4%) required removal due to leg edema or need for venous access. Length of stay was unrelated to clubfoot management. At 9 years, 50% were independently ambulatory. Non-ambulatory status was attributable to underlying diagnoses. All surviving children had plantigrade, braceable feet. These results are limited by a small population and lack of control group but demonstrate clubfoot treatment can be initiated in the inpatient setting with minimal complications [5].

3.4. Non-idiopathic clubfoot

Approximately 11–48% of clubfoot exists as part of a congenital syndrome or neuromuscular disorder [10,13,16,21]. A portion of these patients will be seen in the NICU. Non-idiopathic clubfoot is challenging to treat due to the inherent stiffness of the foot and ankle, frequent relapses, and musculoskeletal and medical comorbidities [1,14,15,34]. A systematic review conducted in 2014 found a substantial dearth of high or moderate quality evidence for the treatment of relapsed, neglected, complex, and non-idiopathic clubfoot [7]. This is in part due to the relatively small number of cases (Table 1). Although the Ponseti method has been extensively studied in idiopathic clubfoot, research on use in non-idiopathic clubfoot is less abundant. Ponseti management can produce good functional outcomes in non-idiopathic clubfoot despite increased relapse rates (15–44%) and greater need for additional surgical procedures compared to idiopathic clubfoot (3% vs. 37%) [1,13,15,16,34].

3.4.1. Arthrogryposis

Arthrogryposis is a group of congenital contracture syndromes involving the upper and lower limbs. Severe rigid clubfoot is present in 78–90% of children with arthrogryposis [37]. Clubfoot in arthrogryposis was historically treated with extensive release that often required revision surgeries [31,33]. Compared to surgical release, the Ponseti method can increase function, reduce revision surgeries, and lessen complications of clubfoot treatment in distal arthrogryposis [31,33,38]. Arthrogrypotic clubfeet require more casts to achieve correction than idiopathic clubfeet (average 7–9, range 4–12), which is positively correlated with the severity of the deformity [28,29,31–33,38]. The relapse rate is significantly higher (25–90%) and not solely due to brace noncompliance [28,29,31–33,38]. A modified Ponseti method with tenotomy performed before and after casting has been successful in treating more severe clubfoot associated with classic

Table 1
Available case studies and retrospective reviews of non-idiopathic clubfoot treated with the Ponseti method.

	Study	No. of patients (no. of feet)	Treatment setting[c]	Average follow-up (in years)[d]	Level of evidence
Mixed non-idiopathic	Gurnett et al. [10]	84 (147)	Outpatient	≥2	II
	Janicki et al. [14]	23 (40)	Outpatient	2.8 (1–5)	II
	Matar et al. [34]	16 (28)	Outpatient	7 (4–12)	IV
	Moroney et al. [15]	29 (43)	Outpatient	3.2 (1–5.3)	III
	Richards et al. [16]	47 (N/A)	N/A	≥2	IV
Arthrogryposis	Boehm et al. [28]	12 (24)	Outpatient	N/A	IV
	Kowalczyk et al. [31]	9 (18)	N/A	7.3 (5–10)	III
	Kowalczyk et al. [32]	5 (10)	N/A	3 (2–3.7)	IV
	Matar et al. [33]	10 (17)	Outpatient	5.8 (3–8)	IV
	Morcuende et al. [29]	16 (32)	N/A	N/A	IV
	Van Bosse et al. [38]	10 (19)	Outpatient	3.2 (1.1–5.8)	IV
Amniotic band syndrome[a]	Agarwal et al. [40]	3 (4)	N/A	≥1	IV
	Carpiaux et al. [36]	12 (21)	N/A	3.9 (0.8–10)	IV
	Zionts et al. [30]	5 (6)	N/A	2.7 (1.8–4.1)	III
Neural tube defects	Abo El-Fadl et al. [42]	24 (48)	N/A	2.3 (2–2.8)	IV
	Arkin et al. [41]	17 (26)	Outpatient	5.4 (1.8–7.8)	III
	Gerlach et al. [12]	16 (28)	N/A	2.8 (2.1–3.6)	II
	Jackson et al. [43]	8 (12)	N/A	2	II
	Matar et al. [35]	11 (18)	Outpatient	4.5 (3–9)	IV
NICU[b]	Lebel et al. [5]	20 (30)	NICU	(2–9)	III

[a] Also referred to in the literature as congenital annular band syndrome and congenital constriction band syndrome.
[b] Mixed idiopathic and non-idiopathic population.
[c] Setting in which treatment was initiated (i.e. NICU, inpatient, outpatient/clinic, not available).
[d] Presented as average (range).

arthrogryposis [38]. The majority of these feet have satisfactory functional outcomes at 8 years [29,33,38].

3.4.2. Amniotic band syndrome (ABS)

ABS is a congenital malformation arising from a separation between the amnion and chorion in utero. This produces fibrous bands that encircle limbs, causing damage during development [36]. Clubfoot is present in 12–56% of children with ABS [37]. Clubfoot in ABS is rigid, complicated by limb amputations, constrictions, nerve palsy, and visceral comorbidities [37,39]. This was historically treated with band release and extensive surgical correction of the clubfoot [39]. In preliminary trials, the Ponseti method in ABS lead to fewer extensive surgical interventions (5–16% of clubfeet) [30,36,40]. Despite a higher rate of relapse (33–83%) than in idiopathic clubfoot, most children exhibit supple plantigrade feet at 10 years [30,36,40].

3.4.3. Neural tube defects

Neural tube defects encompass all conditions where the neural tube fails to close. The most serious of these is myelomeningocele, where neural tissues herniate from within the tube. Foot deformities are present in 60–80% of infants born with neural tube defects, and clubfoot is seen in 30–50% [27,37]. Higher level spinal lesions are associated with more rigid deformities [37,41]. The rate of initial correction is similar to that of idiopathic clubfoot. There are mixed results regarding the number of casts needed to achieve initial correction in this population [12,35,41–43]. Despite relapse in 33–68% of clubfeet, most have good functional outcomes [12,35,41,43]. At 9 years, 83–86% of clubfeet are mobile, plantigrade, and able to fit into orthotics; this is necessary to ensure future independence [12,27,35,37].

In very severe deformities, Ponseti casting with open tenotomy increases the rate of initial correction to 42% in children with neural tube defects and leads to improvement in 90% of clubfeet at 3-year follow-up [42]. Both initial percutaneous (vs. open) tenotomy and higher level spinal lesions are associated with higher rates of relapse [12,41]. Treatment is complicated by insensate skin that can break down in casts and delay wound healing [27,37,41,42].

3.5. Treatment of older infants

Children with clubfoot in the NICU typically start treatment at a later age, often after discharge. Treatment can also be interrupted by medical or social issues [6]. Substantial evidence exists for the successful treatment of idiopathic clubfoot in delayed presentations before walking age [1,2,9,11,44–48]. There is mixed evidence regarding the influence of age on the number of casts required to achieve correction (range 3–12 casts) [9,11,44–46,48–50].

Several studies have shown no correlation between age at start of treatment and relapse, need for open surgical release, or functional outcomes in non-ambulatory children with idiopathic clubfoot under 1 year of age [9,11,44,46,49,50]. Outcomes are comparable to those of infants receiving treatment in the first month of life. This suggests the Ponseti method can be successfully applied even after delayed presentation in idiopathic clubfoot [49]. However, the severity of deformity in the delayed treatment group is often unclear. No study has examined the effect of delayed treatment in the NICU population.

4. Discussion

There is limited literature that addresses how clubfoot is managed in the inpatient setting in medically complicated children (Table 1). The study by Lebel et al. is the only study found that explicitly addresses initiation of clubfoot treatment in an inpatient setting [5]. All other studies included in this review state that the standard of care (outpatient casting) was followed or make no reference to the treatment setting. Lebel et al. examined long-term functional outcomes of inpatient clubfoot treatment, suggesting that the Ponseti method could produce satisfactory outcomes with minimal complications [5]. The main concern regarding casting in the NICU is interference with medical management. Casting can interfere with weight evaluation, which is crucial for monitoring growth. It can also cause skin breakdown, leading to infection. This is of particular concern in children with myelomeningocele and other neurologic deficits. The application and removal of casts can be distressing for the infant and should be approached cautiously. The low reported

rate of unplanned cast removal illustrates that a judicious approach to casting can minimize interruptions in medical care [6].

We presume children in the NICU are best represented in available literature through non-idiopathic clubfoot and management of clubfoot in older infants due to the high prevalence of syndromic clubfoot and delays in treatment initiation [5,6,10,13,16,21]. There is encouraging evidence for the successful outpatient treatment of non-idiopathic clubfoot and idiopathic clubfoot with delayed presentation using the Ponseti method. However, it is unclear if delayed treatment in the non-idiopathic or medically complicated child have worse outcomes.

Developing evidence-based practice guidelines for inpatient clubfoot management is complicated by conflicting evidence on the optimal timing of treatment. Iltar et al. found that children casted between one month and one year of age exhibited more correction, as demonstrated by lower final severity scores, than those casted in the first month of life [50]. These findings are corroborated by Liu et al., who found that children beginning treatment between 28 days and 3 months of life had fewer casts, fewer relapses, and better functional outcomes compared to children casted prior to 28 days of life or from age 3 months to 6 months [48]. Difficulty manipulating a small foot could contribute to these findings. Iltar et al. and Hemo et al. found that children with feet less than 8 cm in length at the start of casting required more casts to achieve correction and had worse severity score after treatment compared to those with feet longer than 8 cm [50,51]. Shorter foot length at treatment initiation has also been associated with an increased incidence of cast slippage and need for further surgical intervention for residual or recurrent deformity [52]. Advantages of early intervention have also been suggested. Neonates exhibit ligamentous laxity, which could improve mobility and amount of correction with each manipulation [33]. Syndromic clubfoot is often more rigid than idiopathic clubfoot, so prompt interventions may increase the effectiveness of casting [1,14,15,33,48]. Bone remodeling is also increased in neonates, which may account for good outcomes seen in severe clubfoot treated early [5,53].

Clinical guidelines are further complicated by inconsistent outcomes measures, resulting in an inability to aggregate data from multiple studies. Standardized use of validated scoring systems and functional measures are needed to facilitate evidence-based protocol development.

5. Conclusion

Children with clubfoot in the NICU have a variety of diagnoses that influence treatment decisions. They can generally be divided into those with idiopathic clubfoot and those with multiple congenital anomalies or an identifiable syndrome. Prognosis and probable course of medical treatment must be weighed when deciding if and when to initiate casting. The presence of congenital anomalies may also impact the severity of deformity and response to treatment. In premature infants, care is further complicated by small foot size and serious medical concerns. Addressing clubfoot may not be considered a priority when facing acute and life-threatening medical problems, but many children in the NICU grow up to be independent adults. The available literature suggests it is possible to begin Ponseti treatment in the NICU without compromising medical management. However, it is unclear if this confers an advantage over the current model of outpatient treatment. Further study is needed to examine the outcomes and optimal timing of Ponseti treatment of clubfoot in the NICU.

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Conflicts of interest

The authors declare that they have no conflict of interest.

Ethics approval

Not applicable for this systematic review.

Availability of data and material

All data and material are cited, described, and available upon request.

Authors' contributions

Sally Trout, BS: Completed systematic review, organized the literature, drafted and edited the paper, approved final manuscript.

Amanda Whitaker, MD: Conceptualization of study, study design, organized the review and paper, assisted with drafting and revised the manuscript, approved final manuscript.

Consent to participate

Not applicable due to systematic review of available literature.

Consent to publish

Not applicable due to systematic review of available literature. No Copyrighted materials are included in this manuscript.

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References

[1] Jowett CR, Morcuende JA, Ramachandran M. Management of congenital talipes equinovarus using the Ponseti method: a systematic review. J Bone Joint Surg Br 2011;93:1160–4, doi:http://dx.doi.org/10.1302/0301-620X.93B9.26947.

[2] Sankar WN, Weiss J, Skaggs DL. Orthopaedic conditions in the newborn. J Am Acad Orthop Surg 2009;17:112–22, doi:http://dx.doi.org/10.5435/00124635-200902000-00007.

[3] Halanski MA, Davison JE, Huang JC, Walker CG, Walsh SJ, Crawford HA. Ponseti method compared with surgical treatment of clubfoot: a prospective comparison. J Bone Joint Surg Am 2010;92:270–8, doi:http://dx.doi.org/10.2106/JBJS.H.01560.

[4] Radler C. The Ponseti method for the treatment of congenital club foot: review of the current literature and treatment recommendations. Int Orthop 2013;37:1747–53, doi:http://dx.doi.org/10.1007/s00264-013-2031-1.

[5] Lebel E, Weinberg E, Berenstein-Weyel TM, Bromiker R. Early application of the Ponseti casting technique for clubfoot correction in sick infants at the neonatal intensive care unit. J Pediatr Orthop B 2017;26:108–11, doi:http://dx.doi.org/10.1097/BPB.0000000000000363.

[6] Tanta KJ, Gunsolus K, Harley N, Grosvenor K, Garcia J, Jirikowic T. Protocol development for infants with orthopedic complications in the NICU. J Occup Ther Sch Early Interv 2012;5:275–92, doi:http://dx.doi.org/10.1080/19411243.2012.750544.

[7] Gray K, Pacey V, Gibbons P, Little D, Burns J. Interventions for congenital talipes equinovarus (clubfoot). Cochrane Database Syst Rev 2014;CD008602, doi:http://dx.doi.org/10.1002/14651858.CD008602.pub3.

[8] Harnett P, Freeman R, Harrison WJ, Brown LC, Beckles V. An accelerated Ponseti versus the standard Ponseti method: a prospective randomised controlled trial. J Bone Joint Surg Br 2011;93:404–8, doi:http://dx.doi.org/10.1302/0301-620X.93B3.24450.

[9] Pavone V, Testa G, Costarella L, Pavone P, Sessa G. Congenital idiopathic talipes equinovarus: an evaluation in infants treated by the Ponseti method. Eur Rev Med Pharmacol Sci 2013;17:2675–9.
[10] Gurnett CA, Boehm S, Connolly A, Reimschisel T, Dobbs MB. Impact of congenital talipes equinovarus etiology on treatment outcomes. Dev Med Child Neurol 2008;50:498–502, doi:http://dx.doi.org/10.1111/j.1469-8749.2008.03016.x.
[11] Alves C, Escalda C, Fernandes P, Tavares D, Neves MC. Ponseti method: does age at the beginning of treatment make a difference? Clin Orthop Relat Res 2009;467:1271–7, doi:http://dx.doi.org/10.1007/s11999-008-0698-1.
[12] Gerlach DJ, Gurnett CA, Limpaphayom N, et al. Early results of the Ponseti method for the treatment of clubfoot associated with myelomeningocele. J Bone Joint Surg Am 2009;91:1350–9, doi:http://dx.doi.org/10.2106/JBJS.H.00837.
[13] Jackson T, Jones A, Miller N, Georgopoulos G. Clubfoot and tethered cord syndrome: results of treatment with the Ponseti method. J Pediatr Orthop 2017, doi:http://dx.doi.org/10.1097/BPO.0000000000000944.
[14] Janicki JA, Narayanan UG, Harvey B, Roy A, Ramseier LE, Wright JG. Treatment of neuromuscular and syndrome-associated (nonidiopathic) clubfeet using the Ponseti method. J Pediatr Orthop 2009;29:393–7, doi:http://dx.doi.org/10.1097/BPO.0b013e3181a6bf77.
[15] Moroney PJ, Noel J, Fogarty EE, Kelly PM. A single-center prospective evaluation of the Ponseti method in nonidiopathic congenital talipes equinovarus. J Pediatr Orthop 2012;32:636–40, doi:http://dx.doi.org/10.1097/BPO.0b013e31825fa7df.
[16] Richards BS, Faulks S. Clubfoot infants initially thought to be idiopathic, but later found not to be. How do they do with nonoperative treatment? J Pediatr Orthop 2019;39:42–5, doi:http://dx.doi.org/10.1097/BPO.0000000000000984.
[17] Chotel F, Parot R, Seringe R, Berard J, Wicart P. Comparative study: Ponseti method versus French physiotherapy for initial treatment of idiopathic clubfoot deformity. J Pediatr Orthop 2011;31:320–5, doi:http://dx.doi.org/10.1097/BPO.0b013e31820f77ba.
[18] Clarke NM, Uglow MG, Valentine KM. Comparison of Ponseti versus surgical treatment in congenital talipes equinovarus. J Foot Ankle Surg 2011;50:529–34, doi:http://dx.doi.org/10.1053/j.jfas.2011.04.040.
[19] Morcuende JA, Dolan LA, Dietz FR, Ponseti IV. Radical reduction in the rate of extensive corrective surgery for clubfoot using the Ponseti method. Pediatrics 2004;113:376–80, doi:http://dx.doi.org/10.1542/peds.113.2.376.
[20] O'Shea RM, Sabatini CS. What is new in idiopathic clubfoot? Curr Rev Musculoskelet Med 2016;9:470–7, doi:http://dx.doi.org/10.1007/s12178-016-9375-2.
[21] Siapkara A, Duncan R. Congenital talipes equinovarus: a review of current management. J Bone Joint Surg Br 2007;89:995–1000, doi:http://dx.doi.org/10.1302/0301-620X.89B8.19008.
[22] Smith PA, Kuo KN, Graf AN, et al. Long-term results of comprehensive clubfoot release versus the Ponseti method: which is better? Clin Orthop Relat Res 2014;472:1281–90, doi:http://dx.doi.org/10.1007/s11999-013-3386-8.
[23] Graf A, Wu KW, Smith PA, Kuo KN, Krzak J, Harris G. Comprehensive review of the functional outcome evaluation of clubfoot treatment: a preferred methodology. J Pediatr Orthop B 2012;21:20–7, doi:http://dx.doi.org/10.1097/BPB.0b013e32834dd239.
[24] Dyer PJ, Davis N. The role of the Pirani scoring system in the management of club foot by the Ponseti method. J Bone Joint Surg Br 2006;88:1082–4, doi:http://dx.doi.org/10.1302/0301-620X.88B8.17482.
[25] Zhang W, Richards BS, Faulks ST, Karol LA, Rathjen KA, Browne RH. Initial severity rating of idiopathic clubfeet is an outcome predictor at age two years. J Pediatr Orthop B 2012;21:16–9, doi:http://dx.doi.org/10.1097/BPB.0b013e32834c31a2.
[26] Agarwal A, Gupta N. Does initial Pirani score and age influence number of Ponseti casts in children? Int Orthop 2014;38:569–72, doi:http://dx.doi.org/10.1007/s00264-013-2155-3.
[27] Brown JP. Orthopaedic care of children with spina bifida: you've come a long way, baby!. Orthop Nurs 2001;20:51–8, doi:http://dx.doi.org/10.1097/00006416-200107000-00009.
[28] Boehm S, Limpaphayom N, Alaee F, Sinclair MF, Dobbs MB. Early results of the Ponseti method for the treatment of clubfoot in distal arthrogryposis. J Bone Joint Surg Am 2008;90:1501–7, doi:http://dx.doi.org/10.2106/JBJS.G.00563.
[29] Morcuende JA, Dobbs MB, Frick SL. Results of the Ponseti method in patients with clubfoot associated with arthrogryposis. Iowa Orthop J 2008;28:22–6.
[30] Zionts LE, Habell B. The use of the Ponseti method to treat clubfeet associated with congenital annular band syndrome. J Pediatr Orthop 2013;33:563–8, doi:http://dx.doi.org/10.1097/BPO.0b013e31829178fd.
[31] Kowalczyk B, Felus J. Ponseti casting and Achilles release versus classic casting and soft tissue releases for the initial treatment of arthrogrypotic clubfeet. Foot Ankle Int 2015;36:1072–7, doi:http://dx.doi.org/10.1177/1071100715581656.
[32] Kowalczyk B, Lejman T. Short-term experience with Ponseti casting and the Achilles tenotomy method for clubfeet treatment in arthrogryposis multiplex congenita. J Child Orthop 2008;2:365–71, doi:http://dx.doi.org/10.1007/s11832-008-0122-0.
[33] Matar HE, Beirne P, Garg N. The effectiveness of the Ponseti method for treating clubfoot associated with arthrogryposis: up to 8 years follow-up. J Child Orthop 2016;10:15–8, doi:http://dx.doi.org/10.1007/s11832-016-0712-1.
[34] Matar HE, Makki D, Garg NK. Treatment of syndrome-associated congenital talipes equinovarus using the Ponseti method: 4–12 years of follow-up. J Pediatr Orthop B 2017, doi:http://dx.doi.org/10.1097/BPB.0000000000000434.
[35] Matar HE, Beirne P, Garg NK. Effectiveness of the Ponseti method for treating clubfoot associated with myelomeningocele: 3–9 years follow-up. J Pediatr Orthop B 2017;26:133–6, doi:http://dx.doi.org/10.1097/BPB.0000000000000352.
[36] Carpiaux AM, Hosseinzadeh P, Muchow RD, Iwinski HJ, Walker JL, Milbrandt TA. The effectiveness of the Ponseti method for treating clubfoot associated with amniotic band syndrome. J Pediatr Orthop 2016;36:284–8, doi:http://dx.doi.org/10.1097/BPO.0000000000000444.
[37] van Bosse HJ. Syndromic feet: arthrogryposis and myelomeningocele. Foot Ankle Clin 2015;20:619–44, doi:http://dx.doi.org/10.1016/j.fcl.2015.07.010.
[38] van Bosse HJ, Marangoz S, Lehman WB, Sala DA. Correction of arthrogrypotic clubfoot with a modified Ponseti technique. Clin Orthop Relat Res 2009;467:1283–93, doi:http://dx.doi.org/10.1007/s11999-008-0685-6.
[39] Walter Jr. JH, Goss LR, Lazzara AT. Amniotic band syndrome. J Foot Ankle Surg 1998;37:325–33, doi:http://dx.doi.org/10.1016/s1067-2516(98)80070-7.
[40] Agarwal A, Shaharyar A, Kumar A. Clubfoot associated with congenital constriction band: the Ponseti method perspective. Foot Ankle Spec 2015;8:230–3, doi:http://dx.doi.org/10.1177/1938640014565049.
[41] Arkin C, Ihnow S, Luciano D, Swaroop VT. Midterm results of the Ponseti method for treatment of clubfoot in patients with spina bifida. J Pediatr Orthop 2018;38:e588–92, doi:http://dx.doi.org/10.1097/BPO.0000000000001248.
[42] Abo El-Fadl S, Sallam A, Abdelbadie A. Early management of neurologic clubfoot using Ponseti casting with minor posterior release in myelomeningocele: a preliminary report. J Pediatr Orthop B 2016;25:104–7, doi:http://dx.doi.org/10.1097/BPB.0000000000000236.
[43] Jackson T, Jones A, Miller N, Georgopoulos G. Clubfoot and tethered cord syndrome: results of treatment with the Ponseti method. J Pediatr Orthop 2019;39(6):318–21, doi:http://dx.doi.org/10.1097/BPO.0000000000000944.
[44] Bor N, Herzenberg JE, Frick SL. Ponseti management of clubfoot in older infants. Clin Orthop Relat Res 2006;444:224–8, doi:http://dx.doi.org/10.1097/01.blo.0000201147.12292.6b.
[45] Verma A, Mehtani A, Sural S, et al. Management of idiopathic clubfoot in toddlers by Ponseti's method. J Pediatr Orthop B 2012;21:79–84, doi:http://dx.doi.org/10.1097/BPB.0b013e328347a329.
[46] Zionts LE, Sangiorgio SN, Cooper SD, Ebramzadeh E. Does clubfoot treatment need to begin as soon as possible? J Pediatr Orthop 2016;36:558–64, doi:http://dx.doi.org/10.1097/BPO.0000000000000514.
[47] Goksan SB, Bursali A, Bilgili F, Sivacioglu S, Ayanoglu S. Ponseti technique for the correction of idiopathic clubfeet presenting up to 1 year of age. A preliminary study in children with untreated or complex deformities. Arch Orthop Trauma Surg 2006;126:15–21, doi:http://dx.doi.org/10.1007/s00402-005-0070-9.
[48] Liu YB, Li SJ, Yu B, Zhao DH. Timing for Ponseti clubfoot management: does the age matter? 90 children (131 feet) with a mean follow-up of 5 years. Acta Orthop 2018;89(6):662–7, doi:http://dx.doi.org/10.1080/17453674.2018.1526534.
[49] Faldini C, Traina F, Nanni M, Sanzarello I, Borghi R, Perna F. Congenital idiopathic talipes equinovarus before and after walking age: observations and strategy of treatment from a series of 88 cases. J Orthop Traumatol 2016;17:81–7, doi:http://dx.doi.org/10.1007/s10195-015-0377-4.
[50] Iltar S, Uysal M, Alemdaroglu KB, Aydogan NH, Kara T, Atlihan D. Treatment of clubfoot with the Ponseti method: should we begin casting in the newborn period or later? J Foot Ankle Surg 2010;49:426–31, doi:http://dx.doi.org/10.1053/j.jfas.2010.06.010.
[51] Hemo Y, Yavor A, Gigi R, Wientroub S. The significance of foot length at the initiation of the Ponseti method: a prospective study. J Child Orthop 2019;13(3):252–7, doi:http://dx.doi.org/10.1302/1863-2548.13.190075.
[52] Ko KR, Shim JS, Kim JH, Cha YT. Difficulties during Ponseti casting for the treatment of idiopathic clubfoot. J Foot Ankle Surg 2020;59(1):100–4, doi:http://dx.doi.org/10.1053/j.jfas.2019.07.022.
[53] Hegazy M, Nasef NM, Abdel-Ghani H. Results of treatment of idiopathic clubfoot in older infants using the Ponseti method: a preliminary report. J Pediatr Orthop B 2009;18:76–8, doi:http://dx.doi.org/10.1097/BPB.0b013e32832988a1.
[54] The PRISMA Group. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 2009;151(4).