Tissue Expansion for Severe Foot and Ankle Deformities: A 16-Year Review

L'expansion tissulaire en cas de graves déformations du pied et de la cheville : une analyse sur 16 ans

Kevin J. Nickel, BSc¹, Aaron C. Van Slyke, MD, MSc²,
Aaron D. Knox, MD, MHPE, FRCSC², Kevin Wing, MD, FRCSC³,
and Neil Wells, MD, FRCSC²

Plastic Surgery
2018, Vol. 26(4) 244-249
© 2018 The Author(s)
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/2292550317749510
journals.sagepub.com/home/psg

Abstract

Background: Tissue expansion in the lower extremity is controversial, with studies reporting complication rates as high as 83%. Few studies have looked at tissue expansion prior to orthopaedic correction of severe foot and ankle deformities, and those available are restricted to clubfoot in the pediatric population. Here, we report the largest case series on the use of tissue expanders for the reconstruction of severe foot and ankle deformity and the only report in adults. **Methods:** This is a retrospective chart review of the senior author's practice over a 16-year study period. All patients over 18 years of age who underwent tissue expansion prior to definitive orthopaedic correction of a severe foot and ankle deformity were included. Patient demographics, etiology of deformity, rate of expansion, and complications were recorded. Major complications were defined as those which required surgical intervention. Data were analyzed using descriptive statistics. **Results:** Nineteen cases were performed on 16 patients. Our overall complication rate was 31.6% (6/19), with major complications occurring in 21.1% (4/19) of cases, and minor complications occurring in 10.5% (2/19) of cases. Despite this, 94.7% (18/19) of cases went on to receive definitive orthopaedic correction after tissue expansion. No demographic parameters were associated with occurrence of complications. **Conclusions:** This represents the largest report on lower extremity tissue expansion for severe foot and ankle deformity correction. While we observed complications in 31.6% of patients, 94.7% of cases went on to receive definitive orthopaedic correction with successful primary closure.

Résumé

Historique : L'expansion tissulaire des membres inférieurs est controversée, car des études font état d'un taux de complications atteignant les 83 %. Peu d'études ont porté sur l'expansion tissulaire avant la correction orthopédique de graves déformations du pied et de la cheville, et celles qui existent se limitent au pied bot dans la population pédiatrique. Les auteurs rendent compte de la plus grande série de cas sur l'utilisation d'expandeurs tissulaires en vue de la reconstruction de graves déformations du pied et de la cheville, la seule à être menée chez des adultes. **Méthodologie :** La présente étude rétrospective traite des dossiers de l'auteur principal sur une période de 16 ans. Tous les patients de plus de 18 ans qui ont subi une expansion tissulaire avant la correction orthopédique définitive d'une grave déformation du pied et de la cheville en ont fait partie. Les chercheurs ont consigné la démographie des patients, l'étiologie des déformations, le taux d'expansion et les complications. Ils ont défini les complications majeures comme celles qui exigent une intervention chirurgicale. Ils ont analysé les données à l'aide de statistiques descriptives. **Résultats :** Les chercheurs ont relevé 19 cas chez 16 patients. Le taux de complications global s'élevait à 31,6 % (six cas sur 19). Des complications majeures se sont produites dans 21,1 % des cas (quatre sur 19) et des complications, mineures, dans 10,5 % des

¹ Faculty of Medicine, University of British Columbia, Vancouver, British Columbia, Canada

² Division of Plastic Surgery, Department of Surgery, University of British Columbia, Vancouver, British Columbia, Canada

³ Department of Orthopedic Surgery, University of British Columbia, Vancouver, British Columbia, Canada

Corresponding Author:

Kevin Nickel, Faculty of Medicine, University of British Columbia, 2775 Laurel St. 11th floor, Vancouver, BC V5Z 1M9.
Email: knickel@alumni.ubc.ca

cas (deux sur 19). Malgré tout, 94,7 % des cas (18 sur 19) ont subi une correction orthopédique définitive après l'expansion tissulaire. Aucun paramètre démographique ne laissait présager les complications. **Conclusions** : La présente étude est le rapport le plus vaste des expansions tissulaires pour corriger de graves déformations du pied et de la cheville. Les auteurs ont observé des complications chez 31,6 % des patients, mais 94,7 % des cas ont profité d'une correction orthopédique définitive et d'une fermeture primaire réussie.

Keywords

complications, contracture, CVA, tissue expansion, equinovarus, lower extremity

Introduction

Tissue expansion in the lower extremity was first described by Manders in 1988 with a complication rate of 80%.¹ Today, lower extremity tissue expansion is still used in reconstruction, despite being known to have greater risks of complication than other body sites.² These complications are likely multifactorial and relate to the position, function, and anatomy of the lower limb. Specifically, the pressure of gravity-dependent edema, propensity for frequent motion, delicate skin, and poorly developed subdermal plexi may all contribute to poor outcomes.²⁻⁴

Mitigating complications associated with skin contracture during equinovarus correction represents a unique indication for tissue expansion in the lower limb. Few reports describe such a strategy, and of these, all cases are in pediatric patients with results being equivocal.⁵⁻⁷ Numerous additional alternatives to tissue expansion have been proposed, each with its own associated pitfalls, these include local and regional flaps, healing by secondary intention, and multiple staged procedures.⁸⁻¹²

Equinovarus foot deformity in adults represents the most common physical deformity observed post cerebrovascular accident (CVA).¹³ Many of the same anatomic challenges faced in the surgical correction of the paediatric clubfoot are present in the adult population with acquired equinovarus deformities. The primary orthopaedic goal is to improve the lower limb function by obtaining a pain free plantigrade (and if required, braceable) foot and ankle complex. In the setting of an acquired equinovarus deformity, the foot and ankle surgeon is faced with a contracted joint capsule, muscle tendon units, and overlying skin. Typically, extensive posteromedial dissection and release of the foot and ankle complex are required to move the foot into the desired plantigrade position. Once here, there are frequent difficulties in closing the posteromedial skin around the critical zone overlying the medial ankle. Avoiding major post-operative wound complications in this patient population is highly desirable.¹³ Tissue expansion in the lower leg for adults undergoing orthopaedic equinovarus correction has yet to be described as a method to address these challenges. Here, we share our 16-year experience with soft-tissue expansion in adults undergoing orthopaedic correction of equinovarus deformity.

Methods

This is a review of the senior author's experience over a 16-year period (2001-2016) at a tertiary care center. All

patients over the age of 18 who underwent tissue expansion by the senior author prior to definitive surgical correction of a severe foot and ankle deformity were included. Charts and operative reports were retrospectively reviewed and data were collected on patient demographics, etiology of deformity, procedures performed, and complications incurred.

Major complications were defined as those which necessitated an additional, unanticipated surgery (expander extrusion, premature removal of expander, peri-prosthetic infection requiring removal of expander). Minor complications were defined as those which complicated the expansion process but did not require surgical intervention (overlying erythema and presumed infection amenable to treatment with conservative measures).

Operative Technique

Placement of the tissue expander occurred in the operating room by the senior author or under his direct supervision. In all cases, patients received a single preoperative dose of antibiotics. A tissue expander was most commonly placed in the posteromedial leg (Figure 1). On 2 occasions, the expander was placed on the dorsum of the foot for a long-standing severe equinus contracture of the ankle with associated hyperextension of all toes at the metatarsophalangeal joints.

In posteromedial leg placement, an axial incision was made on the lower posteromedial leg at a minimum distance of 3 cm away from the anticipated tissue expander site—just inferior and posterior to the medial malleolus at the site of maximal skin contracture. Dissection was carried down to the suprafascial plane, and blunt dissection was then used to create the expander pocket. Hemostasis was achieved, the pocket was irrigated extensively and cleansed with betadine solution, and the tissue expander (Allergan SRS-1006, Upplands Väsby, Sweden) was placed. Using blunt dissection, a small tunnel was then made proximal and anterior to the initial incision for placement of the remote injection port, usually resting on the tibia. A layered closure was then performed. No postoperative antibiotics were used unless otherwise indicated.

In dorsum of foot placement, a longitudinal incision was made over the midfoot, and blunt dissection carried down to make a subcutaneous pocket. Hemostasis was achieved, and the pocket was irrigated extensively and cleansed with betadine solution. The tissue expander was placed (Mentor 350-4309 M, Irvine, CA, USA or Allergan SFS-080, Upplands Väsby, Sweden) and the overlying tissue was closed in layers.

Figure 1. Posteromedial location of tissue expander. The injection port is buried and located on the anterior surface of the leg, most often resting on the tibia. The approach incision used for placement is denoted in red.

In all cases, communication between the orthopaedic surgeon and plastic surgeon ensured that soft-tissue expansion was optimized in accordance with the planned incisions for deformity correction.

Expansion

Serial injections with sterilized normal saline began week 2 postoperatively. Most commonly, this involved filling to 10% of the manufacturer's suggested volume on the first visit, as we have found this volume is suitable for priming the expander for serial expansion without producing too much tension on the overlying skin. At subsequent visits, expansion rates were individualized based on anticipated volume needed, as well as patient and clinical factors (patient and clinic availability, pain, skin tension, medical comorbidities, etc).

Removal

Removal of tissue expanders occurred in the operating room by the orthopaedic team at the time of foot and ankle deformity correction. Appropriate marking incorporating the previous incisions were planned and marked preoperatively. Given that

Figure 2. Plantigrade foot following orthopedic correction involving tendo-Achilles lengthening. Access to the Achilles tendon is obtained from extending the previous scar, depicted in red. Given the redundancy generated from tissue expansion, skin no longer prevents appropriate foot positioning.

the site of maximal soft tissue contracture most commonly occurred near the medial malleolus, redundancy in the skin generated by expansion allowed positioning of the foot in a plantigrade position with no overlying tension. In all cases, there was enough redundant skin to approximate the wound edges for primary closure with the foot maintained in an appropriate position (Figure 2).

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics Version 21. χ^2 tests were used to calculate the association of gender, mobility status, and expander location on complication incidence and ultimate outcome. Logistic regression analysis was used to calculate the association of age on complication status and outcome. Statistical significance was set at $P < .05$.

Results

A total of 16 patients underwent 19 cases of tissue expansion prior to surgical correction of their severe foot and ankle deformity (Table 1). The average patient age was 42 (19-67) years, with males representing 10 of 16 patients (Table 1). Nearly two thirds (10/16) of patients required a wheelchair for mobility secondary to the etiology of their severe deformity (Table 1). The most common etiologies of equinovarus deformity were CVA (6/16) and inherited neuromuscular diseases (5/16). Trauma and compartment syndrome accounted for the remaining cases (Table 1).

Table 1. Patient Demographics Including Age, Gender, Etiology of Equinus Deformity, and Mobility Status.

Patient	Age	Gender	Etiology	Mobility Status
1	50	F	Inherited neuromuscular disorder	Wheelchair
2	32	M	CVA	Wheelchair
3	59	M	Trauma	Ambulatory
4	67	F	CVA	Wheelchair
5	45	M	CVA	Wheelchair
6	35	F	Trauma	Ambulatory
7	30	M	CVA	Wheelchair
8	64	F	CVA	Wheelchair
9	48	M	Trauma	Ambulatory
10	22	F	Inherited neuromuscular disorder	Wheelchair
11	45	M	CVA	Wheelchair
12	31	F	Trauma	Wheelchair
13	19	M	Inherited neuromuscular disorder	Ambulatory
14	36	M	Compartment syndrome	Ambulatory
15	44	M	Inherited neuromuscular disorder	Wheelchair
16	46	M	Inherited neuromuscular disorder	Ambulatory

Abbreviations: CVA, cerebrovascular accident; F, female, M, male.

In 17 of 19 cases, tissue expansion occurred on the posteromedial leg (Table 2). In the remaining 2 cases, the tissue expander was placed on the dorsum of the foot. At the time of placement, an average of 17 mL (5-30 mL) was filled once the skin was closed. Routine expansion began 1-week postoperatively. On average, the expanders were filled to a volume of 175 mL (55-245 mL) over the course of 17 weeks (8-27 weeks) from the time of placement (Table 2).

Complications occurred in 6 of 19 cases (31.9%; Table 3). There were 4 major complications (21.0%) which necessitated an additional surgical procedure or involved loss of the expander. Of these, 1 case did not go on to receive definitive orthopaedic correction, yielding a completion rate of 94.7% (Table 3). Minor complications were seen in 2 cases (10.5%), and both were attributed to superficial soft-tissue infection—treated with temporary cessation of active expansion and a short course of antibiotics.

Statistical analysis of demographic factors revealed no association between age ($P = .27$), gender ($P = .89$), or mobility status ($P = .89$) on complication outcome. Furthermore, location of expander placement on the lower limb failed to reveal an association with complications incurred ($P = .55$).

Discussion

An acquired equinus (plantarflexed) contracture at the ankle joint represents the most common deformity following CVA.¹³ In severe cases, there is an associated inward rotation of the foot and ankle complex, referred to as an equinovarus contracture. Clinically significant equinus contracture occurs in 30% of patients, necessitating use of a wheelchair in most.^{14,15}

While function of the entire lower extremity is typically affected, severe equinovarus deformity at the foot and ankle frequently represents the most disabling aspect. In nonambulators, it interferes with foot placement in the wheelchair. In those who might otherwise ambulate or assist with transfers, severe deformities render the affected extremity completely non-functional. The fixed equinovarus deformities in these patients are rarely amenable to bracing, and therefore, surgical correction by tendon and capsule release may be indicated. In severe equinovarus contracture, skin tension may lead to difficulty with primary closure in the desired and corrected position, as well as pose the risk of potential recurrence of the deformity.^{12,15}

Few methods have been proposed to address this issue, those which have are limited. Pie crusting intact skin has potential to damage underlying structures, may be associated with increased infection rates due to open wounds, and leaves an unfavorable scar.¹⁵ Modified approaches (Cincinnati incision) offer easier primary closure, but compromise the surgical window, thereby limiting the soft-tissue release that can be achieved.¹⁰ Leaving the wound to heal by secondary intention in patients post-CVA is not a preferred option, given they are at risk of complicated wound infections, often have poor nutritional status, and may lead a sedentary lifestyle.¹⁵

In the pediatric population, numerous techniques to optimize primary closure post correction of severe clubfoot (Dimeglio Dimeglio classification grade III-IV) have been proposed. These included regional fasciocutaneous flaps, staging the procedure over 2 consecutive surgeries, and tissue expansion.^{6,7,10,12} Regional flaps provide adequate skin closure but come at the cost of requiring a graft to the donor site. Staging the procedure necessitates a second surgery and has not been found to improve rates of relapse.¹² Tissue expansion is known to have inherent risks by requirement of a second surgery but has been shown to be effective in management of severe cases.^{6,7} Furthermore, it is well-known that flaps generated from tissue expansion have increased vascularity and greater viability when compared to traditional flaps.¹⁶

Despite a considerable complication rate, tissue expansion provides skin of similar texture, sensation, appearance, and hair bearing characteristics. Documented high success rates of tissue expansion, despite complications make it an attractive tool in reconstruction.¹⁷ The high success rate seen in our series is likely due to several controlled variables. We exclusively used remote injection ports, along with a remote incision to the expander pocket, both of which are known to provide favorable results.^{6,17,18} Additionally, our cases were conducted exclusively in adults, who have better reported outcomes than seen in the pediatric population.¹⁹ Finally, we carried out our expansion process over a longer time course than most reports. While this has a theoretical risk of increased infection rates due to prolonged foreign body implantation, our belief is that it lowers rates of overlying skin necrosis and wound dehiscence.

While our success rate was high, our complication rate was on par with existing literature. The complications seen in our series were not related to sex, age, mobility status, or location

Table 2. Parameters of Tissue Expansion Process Including Location of Expander, Initial Volume Filled, Total Volume Filled, and Time From Placement to Removal.

Patient	Leg	Location of Expander	Initial Volume Filled (mL)	Volume Expanded (mL)	Time from Insertion to Case (weeks)
1	R	Posterior aspect lower calf	20	170	9
	L	Posterior aspect lower calf	20	235	21
2	R	Posterior aspect lower calf	20	185	22
3	L	Posterior aspect lower calf	20	245	14
4	R	Posterior aspect lower calf	18	158	21
5	L	Posterior aspect lower calf	10	185	18
6	R	Posterior aspect lower calf	10	95	11
7	R	Posterior aspect lower calf	20	155	23
	L	Posterior aspect lower calf	20	55	23
8	L	Posterior aspect lower calf	30	Removed	Removed
9	L	Posterior aspect lower calf	20	210	16
10	R	Posterior aspect lower calf	20	235	12
	L	Posterior aspect lower calf	20	235	12
11	R	Posterior aspect lower calf	10	235	17
12	L	Posterior aspect lower calf	25	205	8
13	R	Dorsum of foot	10	150	14
14	L	Posterior aspect lower calf	15	128	20
15	R	Posterior aspect lower calf	10	100	27
16	L	Dorsum of foot	5	Removed	Removed
Total	Cases		Average	Average	Average
16	19		17	175.4	16.9

Abbreviations: L, left; R, right.

Table 3. Summary of Complications During Expansion Process.

Patient Number	Leg	Complication Class	Complication Incurred	Orthopedic Correction
1	R	Major	Wound dehiscence and expander protrusion. Reimplanted with successful expansion	Yes
7	L	Major	Wound dehiscence. Closure with subsequent successful expansion	Yes
8	L	Major	Overlying skin necrosis, subsequent contact reaction to dressing. Removal of tissue expander. Compromise of skin and failed expansion	No
16	L	Major	Surgical site infection requiring operative removal of tissue expander	Yes
9	L	Minor	Overlying erythema. Temporary cessation of expansion, systemic antibiotics. Successful expansion	Yes
15	R	Minor	Superficial blister necrosis overlying expander. Systemic antibiotics and temporary cessation. Successful expansion	Yes

Abbreviations: L, left; R, right.

of the expander. In the single case where tissue expansion prevented orthopaedic correction, the expander was initially filled to 30 mL at the time of implantation and 13 mL higher than our average initial fill. Furthermore, attempts at controlling this patient's necrosis led to a contact reaction, and ultimately the skin overlying the expander was compromised contributing to failure. To this end, we recommend careful assessment on initial expander placement, a first fill to 10% of the expander capacity, and careful clinical consideration with each subsequent fill for signs of overlying tension which may indicate potential compromise the skin.

Patient selection also deserves attention when such a complication rate is reported. In our series, 10 of 16 patients were wheelchair bound, and thus for these patients, our goal was to improve sitting position as well as ease of transfers. In nonwheelchair-bound patients, severe contracture significantly impaired ambulation and restricted bracing options.

In this population, tissue expansion and deformity correction were therefore indicated to improve ambulation and bracing options. In all patients, tissue expansion was only considered if the orthopaedic surgeon did not believe primary skin closure was easily obtainable at the time of deformity correction. Plastic surgery consultation with a view to soft tissue expansion was utilized as an attempt to avoid massive wound dehiscence/necrosis in this high-risk population; a complication that could necessitate amputation. A careful clinical screen by the plastic surgeon occurred at this consultation. Specific factors assessed included the patients' medical comorbidities as well as the clinical picture of the extremity, particularly skin quality, perfusion status, and whether it was deemed possible for the extremity to accommodate expansion. In our experience, this led to one exclusion over our reported time frame due to scarred skin of poor quality at the proposed expander site.

While our study has provided useful information on lower extremity tissue expansion, and specifically its use for severe equinovarus foot and ankle deformities, the power of our analysis was limited by our sample size. Furthermore, accurate analysis of the benefit tissue expansion provided in these patients would be better elucidated by a prospective analysis, eliminating the biases associated with a retrospective study.

Conclusion

To our knowledge, this represents the largest series of tissue expansion for equinovarus foot and ankle deformity in adults. Despite significant complication rates, adequate expansion was achieved in 94.7% of patients who subsequently went on to have successful deformity correction. We recommend the consideration of lower extremity tissue expansion in this challenging group of patients.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

- Manders EK, Oaks TE, Au VK, et al. Soft-tissue expansion in the lower extremities. *Plast Reconstr Surg*. 1988;81(2):208-219.
- Huang X, Qu X, Li Q. Risk factors for complications of tissue expansion: a 20-year systematic review and meta-analysis. *Plast Reconstr Surg*. 2011;128(3):787-797.
- Vogelin E, de Roche R, Luscher NJ. Is soft tissue expansion in lower limb reconstruction a legitimate option? *Br J Plast Surg*. 1995;48(8):579-582.
- Wang J, Huang X, Liu K, Gu B, Li Q. Complications in tissue expansion: an updated retrospective analysis of risk factors. *Handchir Mikrochir Plast Chir*. 2014;46(2):74-79.
- Bassett GS, Mazur KU, Sloan GM. Soft-tissue expander failure in severe equinovarus foot deformity. *J Pediatr Orthop*. 1993;13(6):744-748.
- Roposch A, Steinwender G, Linhart WE. Implantation of a soft-tissue expander before operation for club foot in children. *J Bone Joint Surg Br*. 1999;81(3):398-401.
- Rosselli P, Rodolfo R, Medina A, Cespedes LJ. Use of a soft tissue expander before surgical treatment of clubfoot in children and adolescents. *J Pediatr Orthop*. 2005;25(3):353-356.
- D'Souza H, Aroojis A, Yagnik MG. Rotation fasciocutaneous flap for neglected clubfoot: a new technique. *J Pediatr Orthop*. 1998;18(3):319-322.
- Lubicky JP, Haluk A. Regional fasciocutaneous flap closure for clubfoot surgery. *J Pediatr Orthop*. 2001;21(1):50-54.
- Rejholec M. Lateroposteromedial approach with rhomboid flap method for the treatment of severe club foot deformity. *Foot Ankle Surg*. 2002;8(4):249-253.
- Ferlic RJ, Breed AL, Mann DC, Cherney JJ. Partial wound closure after surgical correction of equinovarus foot deformity. *J Pediatr Orthop*. 1997;17(4):486-489.
- Uglow MG, Clarke NM. Relapse in staged surgery for congenital talipes equinovarus. *J Bone Joint Surg Br*. 2000;82(5):739-743.
- King BW, Ruta DJ, Irwin TA. Spastic foot and ankle deformities: evaluation and treatment. *Foot Ankle Clin*. 2014;19(1):97-111.
- Keenan MA. The management of spastic equinovarus deformity following stroke and head injury. *Foot Ankle Clin*. 2011;16(3):499-514.
- Reeves CL, Shane AM, Zappasodi F, Payne T. Surgical correction of rigid equinovarus contracture utilizing extensive soft tissue release. *Clin Podiatr Med Surg*. 2016;33(1):139-152.
- Cherry GW, Austad E, Pasyk K, McClatchey K, Rohrich RJ. Increased survival and vascularity of random-pattern skin flaps elevated in controlled, expanded skin. *Plast Reconstr Surg*. 1983;72(5):680-687.
- Antonyshyn O, Gruss JS, Mackinnon SE, Zuker R. Complications of soft tissue expansion. *Br J Plast Surg*. 1988;41(3):239-250.
- Casanova D, Bali D, Bardot J, Legre R, Magalon G. Tissue expansion of the lower limb: complications in a cohort of 103 cases. *Br J Plast Surg*. 2001;54(4):310-316.
- Adler N, Dorafshar AH, Bauer BS, Hoadley S, Tournell M. Tissue expander infections in pediatric patients: management and outcomes. *Plast Reconstr Surg*. 2009;124(2):484-489.