



Revista Española de Cirugía Ortopédica y Traumatología

www.elsevier.es/rot



ORIGINAL ARTICLE

Impact of foot reconstruction surgery on the daily life of patients with cerebrovascular accident sequelae[☆]

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Received 11 June 2011; accepted 28 July 2011

KEYWORDS

Equinovarus;
Reconstructive
surgery;
Tendons transfers;
Spastic hemiplegia;
WalkinSense®

Abstract

Objective: The equinovarus deformity of the foot and digital scrolling is very common among people with sequelae from cerebrovascular accidents. The aim of this study was focused on changes produced by surgical correction of the deformity in terms of comfort, balance, independence and ability to move freely within the context of the daily life of the patient.

Material and methods: The data were evaluated using a retrospective survey and a prospective analysis of gait habits using a recording walking device (WalkinSense®) before and after surgery. All the 15 patients enrolled in the study were submitted to similar surgical procedures of lengthening and tendon transfers.

Results: The use of technical aids to correct the deformity and to aid in walking, as well as painful calluses and difficulties with the shoes and walking on uneven surfaces, decreased significantly. Quantitative analysis of the gait showed that after surgery the patient started to move with smaller steps, although with a higher cadence. Gait analysis also revealed a decrease in the amount of gait segments and speed.

Discussion and conclusions: The results showed a positive development in terms of indicators of comfort, balance, independence and self-image through surgery. However the new way of walking seems to be more tiring for the patients, which could justify a decrease in the number of gait segments and speed.

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[☆] Please cite this article as: Lemos R, et al. Impacto de la cirugía reconstructiva del pie en la vida diaria de los pacientes con secuelas de accidentes vasculares cerebrales. Rev esp cir ortop traumatol. 2012;56(2):98–103.

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PALABRAS CLAVE

Equino varo;
Cirugía
reconstructiva;
Transferencias
tendinosas;
Hemiparesia
espástica;
WalkinSense®

Impacto de la cirugía reconstructiva del pie en la vida diaria de los pacientes con secuelas de accidentes vasculares cerebrales

Resumen

Objetivo: La deformidad del pie en equino varo y garra digital es muy común entre personas con secuelas de accidentes vasculares cerebrales. El objetivo de los autores se centró en la evaluación de las alteraciones producidas por la cirugía de corrección de la deformidad en lo que respecta a confort, equilibrio, independencia y capacidad para la deambulación en el contexto cotidiano de estos pacientes.

Material y métodos: La evaluación de los resultados se realizó a través de un cuestionario retrospectivo y de un análisis prospectivo de los hábitos de deambulación con un dispositivo de registro de marcha (WalkinSense®), antes y después de la cirugía. Los 15 pacientes incluidos en el estudio se sometieron a gestos quirúrgicos de alargamientos y transferencias tendinosas similares.

Resultados: Disminuyeron significativamente la necesidad de ayudas técnicas para corregir la deformidad y para auxiliar la marcha, así como las callosidades dolorosas y las dificultades con el calzado y para la deambulación en pisos irregulares. El análisis cuantitativo de la marcha demostró que tras la cirugía, los pacientes deambulan con pasos menores, aunque con una cadencia mayor. El análisis de la marcha reveló también una disminución en la cantidad de segmentos de más de 12 pasos y en la velocidad de ésta.

Discusión y conclusiones: Los resultados revelan una evolución positiva en los indicadores de confort, equilibrio, independencia e imagen personal con la cirugía. De todas formas, la nueva forma de andar parece cansar más a los pacientes, lo que podrá justificar la disminución del número de segmentos de más de 12 pasos y la reducción de la velocidad de la marcha.

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Introduction

Equinovarus deformity of the foot and ankle with claw toe is very common in patients with hemiplegia, a sequela of stroke.¹⁻³ Incorrect positioning of the distal segment of the lower limb causes difficulties in walking and in orthostatic posture, aside from creating a series of problems that decrease the comfort and personal image of all those who are victims of this problem.

Ever since the description by Mooney and Goodman⁴ in 1969, later popularised by Roper et al.⁵, surgical reconstruction for this paralysed foot deformity in adults has been performed, although it never became as popular as it seemed destined to be. The studies existing in the literature on the modifications induced by muscle rebalancing surgery on the spastic foot focused on 3 relevant aspects:

- Autonomy acquired with respect to technical aids required for walking.⁵⁻⁷
- Space-time evolution of gait in the laboratory.⁶⁻⁸
- Reduction of deformity-associated medical costs.⁹

The authors' research hypothesis was that reconstructive foot surgery promotes a positive evolution in patient comfort and personal image, balance in orthostatic posture and gait, and an increase in independence and amount of walking in the patients' daily life.

This study aimed at exploring the impact of reconstructive foot surgery on a few relevant aspects of the day-to-day life of patients with hemiplegia as a sequela of stroke. The modifications induced by corrective surgery on the deformity were investigated using a retrospective questionnaire

and a prospective study. The study focused on the quantitative walking habits in the pre- and postoperative periods.

Material and methods**Participants**

The study included patients presenting obstructive foot deformity as a stroke sequela, with the deformity being resistant to conservative treatments ($N=15$). Before the decision to operate, all the patients underwent conservative treatment specifically for the foot deformity, through physiatry. Eight patients (8/15) received chemical denervation with botulinum toxin. The surgical indication criteria consisted of the presence of the obstructive deformity, which caused gait problems, and of plantigrade support on the foot in orthostatic position.

All of the patients were operated on between November 2008 and April 2010, after giving prior informed consent. The surgical procedure and patient follow-up included in this study were carried out in the Orthopaedics Service at the Hospital General de Santo António.

Surgical procedure

The same surgeon operated on all of the patients. The surgical intervention consisted of 3 stages designed to correct the deformities according to the principles described by Lawrence,^{10,11} Mooney and Goodman⁴ and Hosalkar et al.¹² The Achilles tendon was lengthened when it was impossible to move the ankle passively to the neutral position, keeping the knee in extension. This lengthening was performed

in step-cut or by triple hemisection using small cutaneous incisions. Claw toe deformity, especially obvious and bothersome in the support phase of the cycle, was treated by flexor digitorum longus and hallux lengthening through the step-cut method in the medial retromalleolar region or by small incisions and tenotomies in the plantar surface of the toes. This step was not performed if the hallux presented extension dystonia. The varus deformity of the foot is commonly seen during the swing phase, sometimes prolonging into the support phase. It was controlled by split tibialis anterior tendon transfer to the outer border of the foot, inserting it at the level of the lateral cuneiform or cuboid bones with 2 bone harpoon anchors.¹²

The anterior tibialis is split by small incisions over the course of the tendon or by a single anterior incision. The osseous anchoring of the transferred half of the anterior tibialis tendon was always accomplished by an independent external incision. If the posterior tibialis contributed to the deformity due to contracture or dystonia, it was also the object of retromalleolar lengthening.

In the postoperative period, all the patients used a posterior brace for 6 weeks. This maintained the ankle and foot in neutral position, with the toes in extension.

After this period, loading began with the temporary use of an ankle-foot orthosis (AFO) brace for 4 weeks; after that, it was not used again at all. Next, patients were encouraged to explore the possibilities of the new foot posture.

Functional stabilisation of the surgical procedure usually occurs after 4 months.

Assessment methods

Three assessment tools were used in this study.

Case history

We compiled information about pre- and postoperative complications.

Retrospective questionnaire

The questionnaire was posted to all the patients' homes 6 months after the surgery and the patients or patient care-takers replied. The objective was to retrospectively explore the modifications produced in the patient's daily life following the operation. We attempted to assess whether the patient noted any improvement/maintenance/worsening of various parameters on comfort and personal image, balance and walking. Enquiries were also made about the use of human or technical aids.

WalkinSense®

WalkinSense® consists of a portable device with 2 components. One of them is applied to the shoe insole and the other to the patient's leg. This device was designed by the bioengineering company Tomorrow Options and is capable of measuring and storing space-time data from the lower limbs during walking. The apparatus can measure and handle long-term storage of data from the patient's gait during

day-to-day walking. It registers parameters such as step distance and gait frequency and speed, as well as distance walked per hour or the number of steps per hour of WalkinSense® use. In our study, the device was used consecutively for a week on the lower limb without patient problems, to ascertain the patient's walking habits quantitatively. The data were assessed prospectively at 2 different times, the first before the surgery and the second, 1 year after it. To eliminate registering short movements that could activate the device but scarcely worthy of being called walking, the authors decided to predefine the technical system to permit storage of data from only gait segments containing 12 steps or more.

Statistical analysis

In the data analysis, a descriptive analysis was originally used, indicating the mean and standard deviation (SD), or ratios, based on how they were applied. Later on, the normality of the study variables was verified using the Shapiro-Wilk test. In the inferential analysis for the comparison of means, Student's *t*-test was used when the study variables presented a normal distribution; if not, we used the Wilcoxon test. A significance level was considered to be $P = .05$ and SPSS software (version 19.0) was used for all of the analyses.

Results

Description of the participants

The study included 15 patients, of whom 11 were males, with the triple deformity consisting of equinus ankle, foot inversion and claw toe. These are characteristic in the hemiplegic foot deformity.

The mean patient age at the time of stroke was 50.3 (SD = 12.5) years and the mean age when the surgery was performed was 56.8 (SD = 13.7). The mean period between stroke and surgery was 5.8 (SD = 3.6) years. The oldest patient who underwent the operation was 71 years old and the youngest, 19 years old. The side affected was the right in 7 patients and the left in 8. The side affected coincided with the dominant side in 6 cases.

Comfort and personal image

In terms of pain and discomfort in the limb, patients noted a positive evolution in 9 cases, with worsening in 3. No changes were noted by 2 patients and 1 did not respond to this question. Following the surgery, all the patients indicated greater ease in using normal footwear. The 8 patients who had foot calluses due to shoe problems indicated improvement in or disappearance of these. Improvement of sensitivity after surgery was reported by 11 patients, while 4 patients did not notice any changes. With respect to general health, 7 patients noticed an improvement, while 8 reported that they had not had any positive evolution from the operation. Three patients indicated improvement in the ease of getting dressed; 12 found no change in this process. The majority of the patients (13/15) reported an improvement in their

Table 1 Patient distribution by number of aids in the pre- and postoperative periods, inside and outside the home.

	No. of aids			
	0	1	2	3
<i>Inside the home</i>				
Preoperative	0	7	3	5
Postoperative	7	3	5	0
<i>Outside the home</i>				
Preoperative	1	2	6	6
Postoperative	3	6	6	0

personal image as well as their quality of life. No case of negative evolution was recorded for comfort and personal image.

Balance

With respect to the kind of aids needed, these can be human (support and supervision) or technical (AFO braces or external support: canes or walkers). Of the 15 study patients, 12 used an AFO brace permanently when at home in the preoperative period. Following the operation, the need for the brace disappeared in 11 cases. One patient returned to using an AFO brace to move around the house 18 months after surgery.

Table 1 presents the patient distribution by number of aids in the pre- and postoperative periods, both inside and outside the home. When asked about their capacity for balance in the orthostatic position, 13 patients reported a positive evolution, 1 patient indicated a negative evolution and the other did not notice any difference in this parameter.

Walking after surgery, most of the patients (10/15) reported improvement in walking around in irregular homes or those that had stairs. However, one third of the cases did not notice any effect. There was positive evolution in voluntary control of the foot affected, with 11 patients indicating improvement.

The gait habits were analysed for several days using the WalkinSense®. During this time, the device was used consecutively outside of the rest periods. On average, the patients used the apparatus 154h in the initial period and 155h in the assessment period following the surgery. Table 2 shows the space-time parametric data used in daily walking before and after the operation.

In relation to the individual perception of gait evolution, each patient classified his or her progression on a scale from 0 to 5. Two patients assessed their evolution as 0 and no patients chose the maximum score. The majority of the answers from the other 13 cases consisted of scores of 3 and 4.

Complications

In this study, 3 patients presented dehiscence of the surgical wounds, all of which resolved with antibiotherapy, dressings and postural drainage. One patient developed chronic oedema of the foot and ankle, making permanent elastic

compression necessary. All of the complications arose in patients having peripheral venous insufficiency and/or diabetes mellitus.

Discussion and conclusions

After their stroke, many patients report, for the lower limb and specifically the foot, a change in sensitivity normally identified as pain or discomfort. That is the reason why we asked the patients to assess whether they noticed any type of positive or negative effect from the surgery in this respect. Improvement was established in a significant group of our patients, although we did not find any explanation for this phenomenon in the literature. Globally, the results for personal comfort were fairly positive, the only adverse effect being the increase in foot discomfort reported by 3 of the patients. The need for an AFO brace made almost all of the patients use adapted footwear, which is generally undiversified, anti-aesthetic and inappropriate for summer weather. The boot normally has to be larger, because space is needed for the orthosis. These conditions create a footwear problem that surgical treatment solved for all our patients. Likewise, the deformities can cause painful calluses (especially on the toes) by footwear conflict and excessive pressure against the ground. Once again, the operation demonstrated a beneficial effect in this aspect.

The evolution in balance, both in walking as well as in standing in orthostatic position, was assessed indirectly through the patient's need for human or technical aid in the pre- and postoperative periods, inside and outside of the home. The number of aids required for walking in the house was significantly less in the postoperative period. Almost half of the sample became absolutely independent of aid inside the home, while the other half indicated a reduction in the use of aid. Outside, in the preoperative period, 14 patients needed to use an AFO brace, with this need disappearing completely following corrective surgery. The assessment of the number of aids required for walking outside of the home differed when comparing the pre- and postoperative periods, although to a lesser extent than the results inside the home. This can be explained by the greater sensation of safety patients have with the use of aids outside.

Following the operation, gait increased in pace, although with shorter steps. This produced a global decrease in speed. The mean number of segments dropped significantly. In the two periods, the mean number of steps per segment remained stable, with no statistically significant pre- and postoperative differences. The number of steps per hour of apparatus use and the daily distance covered in segments of more than 12 steps both were significantly greater following surgery.

The innovative conclusions with respect to other studies on this subject⁴⁻⁹ consist of the demonstration that there is a substantial improvement in patient comfort, with the possibility of using normal footwear and the decrease in problems with painful calluses. Another important aspect cleared up by the study is the improvement in foot sensitivity with better floor recognition. From the qualitative point of view, patient gait evolved positively, allowing them to walk more independently of human and technical aid

Table 2 Mean values for the parameters of day-to-day walking assessed by the WalkinSense® before and after the operation, and the respective *P* value of the comparison of means tests for paired samples.

	Preoperative mean	Postoperative mean	<i>P</i>
Length of use (h)	153.87	154.60	0.999 ^b
Pace (steps/m)	66.907	7.28	0.026 ^a
Speed (m/s)	0.19	0.11	0.002 ^b
Daily distance (m)	644.33	230.72	0.001 ^b
Length of 2 steps (m)	0.30	0.17	0.005 ^b
Step angle (graus)	37.35	31.93	0.088 ^a
No. of segments	497.5	3333.93	0.004 ^a
Duration of the segments (s)	15 356.60	8251.20	0.001 ^a
No. of steps	17 112.07	10 018.13	0.002 ^a
Steps per segment	25.93	28.00	0.502 ^a
Steps per hour	107.33	64.93	0.002 ^a

^a *t*-Test.

^b Wilcoxon test.

and reducing difficulties with irregular ground and with stairs.

Viewed quantitatively, our study indicates that postoperative gait showed shorter steps and a more rapid rhythm. This situation can tire the patient more and could explain the significant reduction in the number of gait segments of 12 or more steps. These findings point to the conclusion that the new manner of walking is perhaps more demanding in terms of energy in comparison to preoperative gait. The hypothetical advantages of the equine gait for hemiplegic patients were already indicated by Kerrigan et al.¹³ and can be seen in our work through the analysis of gait segments. These undergo sharp losses in both frequency and overall time used in their performance. We are convinced that the new manner of walking is more perfect, but that it is also more tiring, which leads the patients to tend to walk less. The fact that all the laboratory studies carried out use small corridors^{5,6,8,14,15} makes it impossible for those studies to have access to this observation.

Our study presents some limitation due to the limited number of cases analysed and to the control of a few variables, a situation inherent in the study type. We point out the fact that the analysis carried out with the WalkinSense® involves a substantially different burden of human and technical aids in the 2 periods. This difficulty is due to the impossibility of knowing in advance how much independence each patient will experience, as well as the impossibility of returning for a week to the aids abandoned so as to carry out the second test. It is also necessary to perform comparative studies on several treatments available, whose selection currently depends heavily on individual experience.¹⁶

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this investigation.

Confidentiality of Data. The authors will declare that they have followed the protocols of their work centre on the publication of patient data and that all the patients included in the study have received sufficient information and have

given their informed consent in writing to participate in that study.

Right to privacy and informed consent. The authors must have obtained the informed consent of the patients and /or subjects mentioned in the article. The author for correspondence must be in possession of this document.

Conflict of interests

The authors have no conflict of interests to declare.

Level of evidence

Level of evidence IV.

Acknowledgements

The authors wish to thank the staff at the company Tomorrow Options for their unselfish collaboration with this study. Special thanks go to the engineers Paulo Ferreira dos Santos, João Neiva, Jorge Pinto and to Dr Isabel Fonseca.

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