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The treatment of fixed contracture of the gastrosoleus in cerebral palsy using the Baumann procedure: preliminary results of a prospective study

Khaled L. El-Adwar, Abdul-Rahman El-Rashidi and Ehab M. Al-Magrabri

ABSTRACT

Background

Equinus deformity is commonly encountered in children with spastic cerebral palsy. The aim of this work was to assess the results of the Baumann procedure in the treatment of fixed contracture of the gastrosoleus muscle in children with spastic cerebral palsy.

Methods

In a prospective study, 20 limbs in 15 ambulant children with fixed equinus were treated using the Baumann procedure. The mean age at surgery was 9 years (range, 6 to 16 years). There were 15 limbs (75%) in 10 diplegic patients and five limbs (25%) in five hemiplegics. Physical examination included assessment of active and passive deficits in range of ankle dorsiflexion, the power of ankle plantarflexion using the Medical Research Council grading system and the presence of deformities in other lower limb joints. Gait video recording was carried out preoperatively and postoperatively. The mean degree of preoperative equinus deformity was 53° (range, 30–75°). All involved limbs showed a negative Silfverskiöld test. Preoperatively, 11 patients walked unsupported and four mobilized with support. Seven limbs (35%) required simultaneous hamstring lengthening. Eleven limbs (55%) had a mild hip flexion deformity (10–15°), which had no operative correction.

Results

The average follow-up was 11.3 months. Satisfactory results were obtained in 16 limbs (80%), while an unsatisfactory outcome was seen in four limbs (20%), namely, recurrence in two limbs (10%), under correction in one and dynamic equinus gait in one.

Conclusions

The Baumann procedure is effective for the treatment of fixed equinus in diplegic and hemiplegic spastic cerebral palsy. Simultaneous hamstring lengthening, smaller degrees of hip flexion deformity and unsupported ambulation preoperatively had a positive effect on the final result.

Keywords

Baumann, fixed equinus, overcorrection, recurrence, spastic cerebral palsy

Department of Orthopaedic Surgery and Traumatology, Hadra Orthopaedic University Hospital, Alexandria, Egypt
Correspondence to Khaled L. El-Adwar, DrCH Orth, MCh Orth, FRCS Tr and Orth, 30 Maarouf El-Rasafi, Roushdi, Alexandria, Egypt
Tel: +002 012 3281957; fax: +002 03 5852326;
e-mail: khaled_eladwar@yahoo.com

INTRODUCTION

Spastic equinus contracture is the most common deformity of the lower extremity in children with cerebral palsy.[1] Contracture of the gastrocnemius, predominantly, and the soleus muscles are responsible for the equinus deformity.[2] Inadequate opposition from the anterior tibial musculature results in a dominance of the triceps surae (TS), which can in time lead to fixed contracture in a growing child.[3]

Treatment includes repeated passive stretching, manipulation, bracing, or denervation of the components of the TS or lengthening it operatively.[1,4] The two principle operative approaches of lengthening include Achilles tendon or fascial lengthening of the aponeurosis covering the gastrocnemius. Both carry a risk of recurrence of the deformity or overcorrection with resultant calcaneal deformity, crouch and diminished strength for push-off during gait.[5–10] The latter two complications are of concern because they interfere significantly and often permanently with the basic function of the TS.[3]

Intramuscular lengthening of the gastrocnemius and soleus was first described by Baumann and Koch[11] in spastic tetraplegia and diplegia. In two other studies from a different institute, its use was recommended in fixed equinus contracture as part of a single-stage, multilevel surgery in diplegic patients.[12,13] The procedure involves division of plantaris tendon, multiple incisions in the ventral aponeurosis of the gastrocnemius and the dorsal aponeurosis of the soleus.

The aim of this work was to assess the results of the Baumann procedure as a method of treatment for fixed contracture of the gastrosoleus in spastic cerebral palsy.

MATERIALS AND METHODS

This is a prospective study of 20 limbs with fixed gastrosoleus contracture in 15 patients with spastic cerebral palsy. Institutional Review Board approval was obtained for this study. All patients were treated using the Baumann procedure. Children with athetoid cerebral palsy were excluded from the study.

The age of the patients ranged from 6 to 16 years with a mean of 9 ± 3.1 years. There were 12 boys (80%) and 3 girls (20%). Fifteen limbs (75%) in 10 diplegic patients were affected and five limbs (25%) in five patients with hemiplegia. Among the 10 patients with diplegia, five patients had

only one limb affected (the two limbs were asymmetrically affected, which is not uncommon in diplegic patients), and the remaining five had bilateral involvement. Preoperatively, 11 patients mobilized unsupported (73.3%) and four walked using two crutches (26.7%).

Equinus deformity ranged from 30–75° with a mean of 53° (with the knee extended, the subtalar joint inverted, and the ankle passively dorsiflexed). The degree of equinus was measured by the third author (EMA) preoperatively and at follow-up, using a goniometer from the medial aspect of the foot. Measurements were made, by aligning one limb of the measuring device parallel to the long axis of the leg and the other limb parallel to the sole of the hind part of the foot. All involved limbs showed a negative Silfverskiöld test (with residual equinus even after knee flexion), denoting contracture of both the gastrocnemius and the soleus muscles.[12,14] Physical examination included assessment of active and passive deficits in range of ankle dorsiflexion and power of ankle plantarflexors using the Medical Resarch Council (MRC) grading system (0 to 5). Seven of the 20 limbs showed a dynamic knee flexion deformity, with an abnormal popliteal angle of more than 40°, and these required simultaneous hamstring fractional lengthening.[15]

Eleven limbs had a hip flexion deformity of 10–15°, which required no correction. Gait video recording of all patients was performed in the coronal and sagittal planes before surgery. This was considered a base line assessment for comparison with a similar recording at the end of follow-up. Gait assessment was by direct observation and repeated assessment of video tapes before surgery and at follow-up to evaluate the effect of the procedure on the change in each patient's gait.

All patients were radiographically assessed using anteroposterior and lateral plain views of the ankle to exclude patients with flat-top talus, which might prove difficult to reduce in the mortise and render the procedure ineffective. All patients were subjected to intramuscular lengthening of the gastrocnemius and soleus muscles as described by Baumann and Koch.[11]

Operative Procedure[11,12]

With the patient under general anesthesia, the Silfverskiöld test was repeated to confirm the contractural nature of the equinus deformity. The test proved negative in all operated limbs. The patient was then positioned supine, a thigh pneumatic tourniquet applied, and the knee, leg and foot were sterilized and draped. The surgeon was seated on the other side of the operated extremity so that he would face the medial side of the affected leg. An 8–12 cm longitudinal medial incision was made, centered over the junction of the proximal and middle thirds of the leg (Figure 1). In the subcutaneous fat, the long saphenous vein and saphenous nerve were identified and gently retracted. The deep fascia was divided and the plane between the gastrocnemius and soleus identified by the presence of a fat pad between the two muscles. Using the gloved finger, the plane was opened from medial to lateral (Figure 2). The plantaris tendon was identified and divided.

FIGURE 1. Operative photograph demonstrating the skin incision.

The foot was then dorsiflexed to put tension on the strong ventral aponeurosis covering the two heads of the gastrocnemius. Starting proximally, the aponeurosis was divided by two to four incisions (according to the size of the muscle), 1.5 cm apart in a transverse direction. Division laterally was carried out with fine sharp scissors. The more the number of incisions made across the aponeurosis, the better the correction of the equinus deformity and the more even the distribution of tension across the underlying muscle fibers will be, therefore not risking muscle tear. The median raphe between the two heads also was cut. An attempt was always made to preserve the distal tendon sheath of the gastrocnemius, which blends into the Achilles tendon. However, in two limbs the cuts were too distal that disruption of the muscle fibers occurred, but luckily this had no untoward effect on the results during follow-up. In the dorsal aponeurosis of the soleus, similar incisions were made somewhat distally to avoid overlap and adhesions with those in the gastrocnemius. The ankle was then dorsiflexed with the knee in extension, until a plantigrade (neutral) position was achieved and separation of the gastrocnemius and soleus aponeuroses was seen.

Overlap between the divisions in the aponeuroses of the two muscles was not always avoidable in the younger patient and the more the number of cuts (Figure 3). In three limbs, in

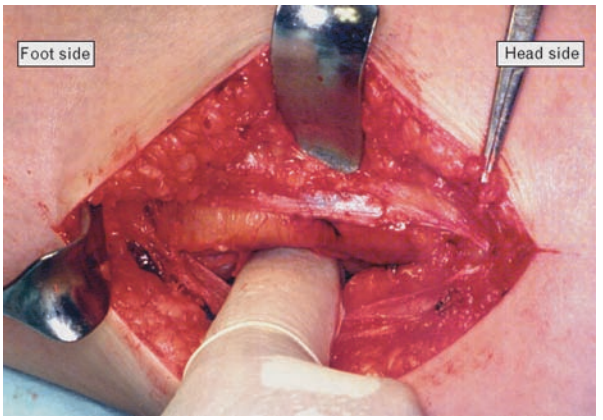

FIGURE 2. Plane between the gastrocnemius and soleus identified by the presence of a fat pad.

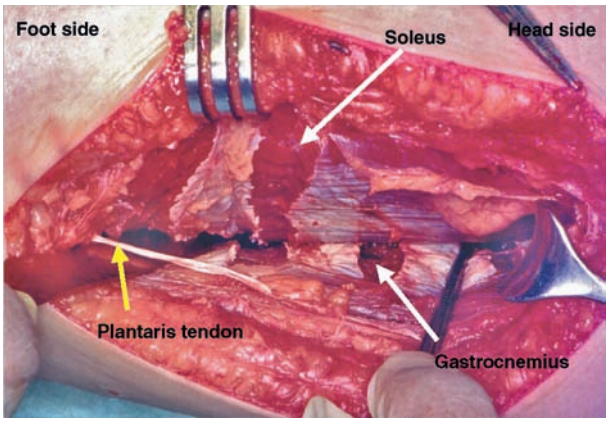

FIGURE 3. After division of the plantaris tendon and the opposing aponeuroses of gastrocnemius and soleus. The amount of separation of the white colored aponeuroses reflects the amount of correction. Note some overlap between the divisions in both muscles.

spite of making four incisions in the gastrocnemius and three in the soleus, there was 5–10° of undercorrection on dorsiflexing the ankle with the knee extended. However, at change of cast 3 weeks postoperatively, the foot reached the plantigrade position, and these patients showed no residual equinus during follow-up. The incision was then closed in layers after tourniquet release and hemostasis.

A nonweight bearing above-knee cast was then applied with the ankle in neutral position and the knee in full extension. Three weeks later under general anesthesia, the cast was replaced with an above or below-knee walking cast, the former being used in patients who had hamstring lengthening. After 3 additional weeks, this final cast was removed. During the 6-week-period of cast immobilization, all patients were advised to straight leg raise the casted limb to reinforce the quadriceps. They were also given Tizanidine, one tablet twice daily, as a muscle relaxant. After cast removal, all patients were fitted with a rigid ankle-foot orthosis (AFO), which they used part of the day and at night to maintain correction and prevent recurrence of the deformity especially in the presence of weak dorsiflexors. Parents were advised to keep the splints until cessation of growth. Patients who had additional hamstring lengthening were fitted with a knee-ankle-foot orthosis (KAFO) for weight bearing to compensate for quadriceps weakness and extensor lag at the knee. The KAFO was used until patients regained satisfactory quadriceps power, thereafter it was replaced by an AFO.

Patients attended regular outpatient visits every 2 months for clinical re-assessment. The follow-up period ranged from 6 months to 2 years with an average of 11.3 months. Gait video recording was repeated at least 6 months postoperatively.

Method of Assessment of the Results

The results were evaluated according to a modification of the method used by Banks and Green.[16] This method is based solely upon the functional performance at the final examination as regards to stance, gait, active and passive dorsiflexion of the ankle joint, power of plantarflexors and associated foot deformity. The results were graded as:

Excellent: heel toe gait without hyperextension of the knee, presence of active and passive dorsiflexion of the foot to neutral or beyond with knee extended, and adequate push off

Good: foot strikes the ground in gait as a unit and clears well, passive dorsiflexion to neutral or beyond with the knee extended, and no decrease in the power of plantarflexors

Fair: planting the foot as a unit when walking, but the heel strikes last, passive dorsiflexion not reaching neutral with the knee extended, and decrease in the power of plantar flexors

Poor: toe-heel gait with hyperextended knee or tip toe gait, passive dorsiflexion not reaching plantigrade even with the knee flexed, and significant calcaneal deformity

Excellent and good results were considered satisfactory, while fair and poor were termed unsatisfactory. Chi-square and Student t-test were used to analyze the results, where P values of less than 0.05 were considered statistically significant.

RESULTS

At the end of follow-up, according to the method of assessment, the overall result of the 20 treated limbs was good (satisfactory) in 16 limbs (12 patients; 80%), and poor (unsatisfactory) in four limbs (three patients; 20%). The unsatisfactory results were due to recurrence of equinus in two limbs (one diplegic patient; 10%), undercorrection in one limb and compensatory (dynamic) equinus in one limb. The latter result was secondary to increasing hamstring contracture with flexion of the knee during stance. On examination, passive ankle dorsiflexion reached beyond plantigrade with the knee extended. This was in a hemiplegic patient with mental retardation who showed poor compliance with use of the AFO.

The mean preoperative equinus deformity in all limbs was $53 \pm 12.3°$ (range, 30–75°), with an insignificant difference between the means of the satisfactory and the unsatisfactory groups ($52.2 \pm 12°$ and $56.3 \pm 14.4°$, respectively). Thus, the severity of the equinus deformity had no significant bearing on the results. Age, sex and anatomical distribution of spasticity (hemiplegia or diplegia) also had no effect on the outcome.

The preoperative ambulatory status had a significant effect on the results ($P = 0.028$). Of 14 limbs in 11 patients who mobilized preoperatively unsupported, 13 limbs (93%) had a satisfactory result. Conversely, of six limbs in four patients who mobilized preoperatively supported, only three limbs (50%) were satisfactory.

In both the satisfactory and unsatisfactory groups, the mean preoperative passive ankle dorsiflexion (PAD/F) improved significantly postoperatively, with the knee in maximal extension and in 90° flexion, ($P < 0.001$ and <0.05, respectively) (Table 1). The mean preoperative active ankle dorsiflexion (AAD/F) improved significantly after surgery in the satisfactory group only, with the knee in maximal extension and in 90° flexion ($P < 0.001$). On the contrary, the improvement in AAD/F among the unsatisfactory

TABLE 1. Relation between the results and range of passive ankle dorsiflexion with the knee in maximal extension and in 90° flexion*

	Knee extended				Knee flexed 90°			
	Satisfactory		Unsatisfactory		Satisfactory		Unsatisfactory	
Passive dorsiflexion	Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op
Minimum	−60	0	−60	−15	−55	0	−40	−10
Maximum	−20	15	−20	5	−15	20	−5	15
Mean ± S.D	−40 ± 9.8	5 ± 4.5	−43.8 ± 17	−6.3 ± 8.5	−31 ± 12.6	10.3 ± 6.5	−28.8 ± 16	2.5 ± 11.9
P value	<0.001		<0.05		<0.001		<0.05	

* The minus sign indicates the deficit in dorsiflexion.

group was statistically insignificant, in both positions of the knee ($P = 0.29$ and 0.23, respectively) (Table 2).

In the satisfactory group, the mean preoperative power of ankle plantarflexors was 2.6 (range, 2 to 4), while postoperatively this improved significantly ($P < 0.001$) to a mean of 3.4 (range, 3 to 5). This also proved sound among the patients in the unsatisfactory group, but was less significant ($P < 0.05$).

The procedure seemed to affect the popliteal angle in limbs in which fractional hamstring lengthening was not performed. Of 13 such limbs, nine (69%) had a satisfactory outcome. The mean preoperative popliteal angle in those nine limbs decreased significantly postoperatively ($P < 0.05$). This was probably due to the fact that the procedure in the satisfactory group relieved the tightness caused by the gastrocnemius muscle across the back of the knee on assessing the popliteal angle. On the other hand, in the remaining four limbs (31%) in which the result was unsatisfactory, the mean preoperative popliteal angle increased insignificantly ($P = 0.09$) postoperatively (Table 3). In all seven limbs in which the hamstrings were lengthened, the result was satisfactory, and when those were compared with the above 13 limbs the difference proved statistically significant ($P = 0.001$), in favor of hamstring lengthening.

The mean preoperative hip flexion deformity was 4.4 ± 6° (range, 0°–15°) among the satisfactory group. While it was 11.3 ± 2.5° (range, 10°–15°) among the unsatisfactory group, and the difference between the groups was statistically significant ($P < 0.05$). This stresses the importance of correcting even mild degrees of hip flexion deformity of 15°.[15] In the 12 patients with a satisfactory outcome, the postoperative gait improved when assessed on video recordings in comparison to the preoperative ones.

It therefore appears that simultaneous hamstring lengthening, smaller degrees of hip flexion deformity and unsupported ambulation preoperatively had a positive effect on the final result.

DISCUSSION

The selection of the ideal treatment for fixed equinus deformity in patients with cerebral palsy remains unsettled and controversial.[13] The available options most commonly used include tendo Achilles lengthening or gastrocnemius recession. The decision of which procedure to carry out depends on the result of performing the Silfverskiöld test under anesthesia. If the test proves negative, tendo Achilles lengthening is carried out while a positive test is an indication for gastrocnemius recession.[17,18] Craig and van Vuren[2] have combined gastrocnemius recession with tendo Achilles lengthening.[2]

The concern of most authors has been to decrease the recurrence rate (range, 5.6–48%) [4,7,8,19] and to prevent the development of a calcaneal deformity (range, 1.4–>40%).[9,10,19] The striking difference in the reported recurrence and overcorrection rates seems to be due to several factors. These include the length of follow-up, which ranged from 1 to 13 years in a number of studies.[7–9,18,20] Higher recurrence rates have been seen when the age at surgery was younger than 5 and 6 years in two different studies.[7,21] Whether the outcome was related to the procedure performed, Sharrard and Bernstein[4] had a higher incidence of recurrent equinus after tendo Achilles lengthening (23%) than after gastrocnemius recession (15%). On the contrary, Yngve and Chambers[20] performed gait analysis before and 1 year after surgery. They found no significant differences in any of the parameters between 22 Vulpius procedures and 27 Z-lengthenings of the Achilles tendon. Furthermore, the type of paralysis had an impact on the outcome in a study by Borton *et al.*[9] with a larger patient population.

TABLE 2. Relation between the results and range of active ankle dorsiflexion with the knee in maximal extension and in 90° flexion*

	Knee extended				Knee flexed 90°			
	Satisfactory		Unsatisfactory		Satisfactory		Unsatisfactory	
Active dorsiflexion	Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op
Minimum	−75	−50	−75	−60	−60	−35	−70	−60
Maximum	−30	15	−30	−25	−25	5	−20	−5
Mean ± S.D	−51.3 ± 12.2	−17.5 ± 17.5	−57.5 ± 19.4	−42.5 ± 20.2	−43.8 ± 11.9	−11.9 ± 13	−15.3 ± 21.8	−32.5 ± 26.6
P value	<0.001		0.291		<0.001		0.23	

* Persistence of the minus sign postoperatively indicates weak dorsiflexors, which take some time to recover power.

TABLE 3. The effect of the procedure on the popliteal angle in the 13 limbs that did not have hamstring lengthening

	Satisfactory $n=9$		Unsatisfactory $n=4$	
Popliteal angle	**Pre-op**	**Post-op**	**Pre-op**	**Post-op**
Minimum	25	20	25	35
Maximum	30	30	35	45
Mean ± S.D	25.6 ± 1.7	22.8 ± 3.6	28.8 ± 4.8	38.8 ± 4.8
P value	<0.05		0.09	

Delp *et al.*,[22] based on a computer simulation study, suggested that in patients with gastrosoleus contracture independent lengthening of the two muscles may be more effective in maintaining strength of plantarflexion and restoring ankle range of motion than tendo Achilles lengthening or aponeurotic lengthening.

Baumann and Koch[11] were the first to describe the use of intramuscular lengthening of the gastrocnemius and the soleus muscles as a treatment method for the correction of equinus deformity in spastic tetraparesis and diplegia. The average age of their patients was 14.1 years, with an equinus deformity that ranged from 5–50°, (less severe than in the present study). The deformity reached 75° in one of our patients, which is quite severe, but the patient had a satisfactory final outcome. This particular patient was advised in another institute to have an Ilizarov correction. This proves the efficacy of the procedure in patients with significant deformities.

There were two further publications on the procedure by an Austrian study group.[12,13] Their patients were diplegic and had multilevel surgery and were assessed both clinically and by gait analysis. The mean age of their patients at surgery was 12.6 years in one study and 14.4 years in the other, with a mean postoperative follow-up of 2.2 and 3.9 years, respectively.[12,13] Despite the fact that the mean age of patients included in the present work was much younger (9 years) than in the above studies, we followed the recommendations of Rattey *et al.*[21] that the minimum age should be 6 years. Identical to our findings, Saraph *et al.*[12] reported no overcorrections and one undercorrection after the Baumann procedure in 28 limbs of 22 diplegic patients. However, they had no recurrences, while in our study there was a 10% recurrence rate.

The Baumann procedure has several advantages, including that it treats[11,12] the thicker and relatively inelastic anterior gastrocnemius aponeurosis and simultaneously lengthens the posterior soleus counterpart. Multiple incisions spread the tension on the muscle fibers during stretching and reduce the danger of muscle rupture. The procedure respects the musculotendinous junction, termed by Ziv *et al.*[23] the ''growth plate'' of the muscle. Furthermore, after surgery the muscle power of the TS is not reduced.

In the current study, the improvement of PAD/F in all patients and AAD/F only in the satisfactory group in both positions of the knee are consistent with findings in the two Austrian studies.[12,13] In the latter study, they also found that the power of ankle plantarflexors improved as assessed clinically but did not reach a significant level as it did in our work. This is in agreement with the observations of Brunner *et al.*[24] in an experimental study on rats, which showed that after aponeurotic lengthening, there was an acute temporary loss of muscle force that recovered completely within 6 weeks. As the principles of physiology are similar, they concluded that in clinical practice, intramuscular lengthening should be considered if muscle force needs to be preserved, accepting a higher risk of recurrence.

Both the Austrian studies[12,13] included children with fixed equinus who walked unsupported and had the ability to comprehend instructions. The level of ambulation seemed to have a significant effect on the outcome of treatment in our work. Of the four unsatisfactory limbs, three (75%) were in two patients who mobilized supported before surgery.

In a study on 27 patients who were followed for 2 to 9 years after tendo Achilles lengthening, Sala *et al.*[25] found that increasing hamstring contracture was the major factor influencing recurrence. Dynamic equinus in one of our patients at follow-up was secondary to hamstring contracture.

In the original technique as described by Baumann and Koch,[11] they divided the gastrosoleus aponeuroses in an oblique direction. Division in a transverse direction was adopted in this work, following the description by Saraph *et al.*[12] For those who will be using the technique for the first time, a number of operative tips should be noted:

(1) dorsiflex the ankle with the knee extended with every single division in any of the aponeuroses, starting the division proximally and moving distally to distribute the tension and gaping evenly at all levels of division.
(2) avoid distal cuts in the gastrocnemius aponeurosis to safeguard against muscle tear.
(3) in severe degrees of equinus, even after the maximum divisions possible, there may an impression of undercorrection on the table, which usually disappears at the time of cast change in 3 weeks.

In this work, we have confirmed the effectiveness of the Baumann procedure for the treatment of fixed equinus deformity in patients with diplegia as well as hemiplegic spastic cerebral palsy while not compromising the strength of the TS. The limitations of this study is the relatively short follow-up, such as that of Kay *et al.*[18] and Yngve and Chambers.[20] Longer follow-up is needed to find out whether the correction will be maintained.

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