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ACHILLES TENOPLASTY FOR CORRECTION OF EQUINUS DEFORMITY IN SPASTIC SYNDROMES OF CEREBRAL PALSY

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Received 18.iv.68

Equinus deformity of the foot in walking is the most common malposition in the lower extremity in children with spastic syndromes of cerebral palsy. Usually this deformity is not an isolated symptom but part of a complex motor disturbance due to abnormally increased stretch reflexes and muscle imbalance. Physical treatment, redression, and plaster fixation are sometimes insufficient, and patients and parents are unwilling to use splints and braces. Moreover, attempts to correct the foot passively against a tight achilles tendon may result in deformity of the forefoot and valgus of the heel (Eggers & Evans 1963).

It is now generally accepted that surgical treatment of the foot equinus in carefully selected cases with a spastic CP-syndrome may be beneficial for gaining function, improving the child's motor development, and preventing secondary deformities. However, divergent opinions still exist as to selection of suitable candidates for operation, optimal age, and advisable type of operative procedure in individual cases. Since the first attempt of Little (1854), the single procedure most frequently used for treatment of contracture or spasticity of the triceps surae has been elongation of the achilles tendon. Tenoplasties were generally found to give more satisfactory results whereas simple subcutaneous tenotomies as a rule were condemned (Hodgen & Franz 1938, McCarrol & Schwartzmann 1942, Lange 1962, Keats 1965).

Equinus relapse as well as occurrence or risk of disabling calcaneus deformity due to overcorrection gave rise to a number of modifications of the original Z-plasty procedures (White 1943, Cummins et al. 1946, Baker 1956, Banks & Green 1958). In order to overcome some dis-

advantages of the tendon elongation procedure, Vulpius (1913) and Strayer (1950, 1958) introduced selective elongation of the gastrocnemius aponeurosis, whereas Silfverskiöld (1924) carried out recession of the gastrocnemius insertions from the femur for the treatment of spastic foot equinus.

The aim of this communication is to present results of 48 consecutive elongations of the achilles tendon by a modified sliding Z-plasty made on 32 children with equinus deformity due to a spastic CP-syndrome. These results will be discussed and compared with those obtained by gastrocnemius recession (Silfverskiöld's procedure 1924) in an earlier and very similar clinical material published in detail elsewhere (Hagberg, Lemperg & Lundberg 1968).

CLINICAL MATERIAL

32 children, 2 to 14 years of age, with cerebral palsy were operated on. Altogether 48 operations were performed. The CP-syndromes were classified as described by d'Avignon et al. (1960). Of the 32 children, 26 were shown to have spastic diplegia, 5 of these combined with ataxia. Five had spastic hemiplegia, one combined with slight ataxia. Finally, one suffered from athetoid movements. Special efforts were made to ensure the diagnosis dystonic tetraplegic syndrome without any real spasticity in which achilles tendon elongation might lead to calcaneus deformity.

11 patients (16 legs) had been operated on previously, on an average 3.0 years earlier by Silfverskiöld's method (gastrocnemius recession). Intrapelvine obturator-nerve resection had been performed on 8 patients (16 legs), on an average 3.5 years earlier. Finally, partial hamstring transfer had been done in 3 cases, in one of them 6 years, in one 4 years earlier. In one patient this operation had been performed bilaterally at the same time as the achilles tendon elongation.

All patients had preoperative physical training at repeated periods for at least one year at the paediatric clinic or at a special institute for CP-children (Folke Bernadottehemmet, Uppsala). This made it possible to evaluate the motor handicaps several times, to follow their development, and to discuss and evaluate the indications for operative treatment with the paediatricians.

Evaluation of Equinus Deformity

The foot equinus was evaluated with and without shoes whilst standing, walking, and, if possible, running. It was noted if the heel struck the floor without compensatory recurvation of the knee joint, valgus of the heel, or abduction of the forefoot. In the *supine* position the classical test (Silfverskiöld) for equinus was carried out with the knee joint flexed at 90° and extended. The last mentioned test, if positive is thought to be significant for the exclusive shortening of the gastrocnemius portion of the triceps surae (positive Silfverskiöld's test).

An attempt was made to obtain a better understanding of the extent to which the gastrocnemius and soleus respectively contributed in weight-bearing as well as in their function as antigravitation muscles to the equinus in spastic CP-syndromes. It could be observed in a number of patients that after a period of quiet standing the heel reaches the floor whilst the knee joint is straight. Even with a slight flexing of the knee, the heel immediately rises from the floor and the foot then remains in equinus even if the knee is flexed 90°. (It is necessary to support the buttocks when performing this test.) This observation could also be made in those patients who had a positive Silfverskiöld's test in the supine position which suggests that the gastrocnemius is the offending muscle producing equinus. This indicates, however, that the soleus functioning as antigravitation muscle may induce equinus which it need not do in the supine position. There is a further source of error to be taken into account in evaluating the equinus in the supine position: the calcaneus may move into valgus during passive dorsiflexion of the foot and therefore mask the equinus.

Efforts were made to evaluate the function and eventual pareses of the *foot extensors*. Good function of the extensors was taken to indicate that the achilles tendon should not be elongated more than required to bring the foot to a right angle at operation.

Indication for Operation

Operation of the equinus deformity was *considered* when continuous physical treatment gave no improvement, or if progress of the deformity was obvious. *Indication* for operation was estimated to be present if the equinus was found (A) to be a serious obstacle to standing or walking ability and (B) to give rise to secondary deformities or malposition of the foot or the whole lower extremity. The total motor pattern was always evaluated and patients lacking enough motor development for walking or an acceptable sense of balance were excluded from operation. Deformities around the hip and knee joints had usually been corrected before if they interfered with function. Mental retardation was not considered to be a contra-indication against operation.

During the last 2-3 years, feet with a more pronounced valgus of the heel and abduction of the forefoot were excluded from achilles tendon elongation alone and primarily treated with stabilization of the subtalar joints. Practically no other operative method was used for treat-

ment of equinus deformity while this series was selected, whether Silfverskiöld's test was found to be positive or not.

Surgical Procedure

A sliding Z-plasty of the achilles tendon was performed identically in all cases. Figure 1A illustrates the incision of the tendon in the frontal plane which is carried proximally to the ventral muscle fibres of the triceps. The knee joint is then brought to an exactly straight position and the foot slowly dorsiflexed to 90°, with the calcaneus in the right position; at the same time possible tight muscle and tendon fibres on the ventral side, including the plantaris tendon, are dissected. This operation can be done without interrupting the continuity of the muscle tendon and without touching the loose connective tissue between the tendon and the dorsal surface of the tibia, thus avoiding scar tissue in this region. The length of the incision in the tendon is usually about 6–10 cm and the lengthening of the tendon necessary for correcting the equinus approximately 2–3 cm. Thus a large contact surface of the cut in the tendon is obtained (Figure 1B). The tendon is sutured with 003 steel wire with 10–12 interrupted sutures. After suturing the tendon, it should not be possible to dorsiflex the foot more than 5–10 degrees with a straight knee, otherwise the tendon must be resutured under greater tension. Peritendineum and subcutaneous tissue are sutured simultaneously with fine catgut, the skin with steel wire. Complete haemostasis is essential.

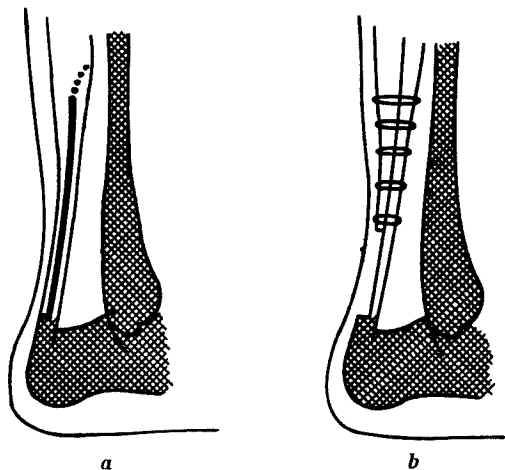


Figure 1a. The incision in the achilles tendon in the frontal plane is marked by uninterrupted line where the tendon is completely divided. The dotted line indicates where the ventral fibres of the triceps are only partially dissected.

Figure 1b. After dorsiflexing the foot to the right angle, the tendon is adapted and sutured with 10–12 interrupted steel wire sutures at a tension which does not allow a dorsiflexion of the foot of more than 5–10° after completing the suture.

The leg, including the thigh, is put in a plaster—the knee joint flexed about 10° and the foot in neutral position. This leg position is more comfortable for the patient than a straight knee joint and maximal dorsiflexed foot. It avoids pressure on the skin, decreases tension in the tendon suture, and does not interfere with the final result. This plaster is exchanged after 3 weeks for a short walking cast which is kept for a further 2–3 weeks.

In those cases where the equinus was completely released during anaesthesia, it was more difficult to get a correct idea as to how much the tendon should be elongated. Some guidance can be obtained by evaluating the degree of equinus by observation of the heel—floor distance in standing and walking. It is advisable in these cases, however, to limit the elongation to approximately 2 cm, this has proved to be sufficient to overcome even equinus of obviously higher degree.

Capsulotomy for correcting the equinus was never necessary. Re-routing of the tibialis posterior tendon, as described by Baker & Hill (1964), was carried out in 3 cases simultaneously with the achilles tendon procedure. All operations, except two, were performed by one surgeon.

Postoperative Treatment

After removal of the plaster the children were treated with physiotherapy to strengthen the dorsiflexors and walking exercises. This treatment was given first at the paediatric department and then continued without interruption during the whole observation period, if possible with 2–3 periods of 2–3 weeks a year hospitalization. A splint was used until normal weight-bearing was achieved and then discarded if there were no other deformities requiring the use of splints. During the continuous follow-up in this series, in no case was it necessary to re-apply splints for treatment of incidental recurrence of the equinus.

RESULTS

Estimating the results of a single operative procedure in children with a CP-syndrome is a difficult undertaking owing to the manifold factors influencing the clinical picture. The general motor pattern might be altered by mental and physical development and additional treatment after the operation. The results in this study were therefore not classified primarily by subjective definitions such as excellent, good, etc.,

Table 1. Comparison of results of achilles tendon elongation and gastrocnemius recession in age groups 2-7 and 7-14 years at operation

	No. of cases	No. of feet	Mean observ. time (yrs)	The appearance of the foot under gait or weight-bearing						"Poor" results
				Heel on floorb	Heel on floorc	Ball-heel gait	Valgus def.	Varus def.		
<i>Achilles tendon elongation</i>										
2-7 years	16	24	2.2	24	-	2	17	-	-	3d
7-14 years	16	24	2.0	24	-	-	18	-	-	3c
<i>Gastrocnemius recession</i>										
2-7 years	19	28	2.5	8	2	3	14	6	6	18d
7-14 years	11	15	4.6	4	1	-	6	4	4	9d

a These results have been reported in detail elsewhere (Hagberg, Lemperg & Lundberg 1968).

b Without hyperextension of the knee joint.

c With hyperextension of the knee joint.

d Persisting equinus.

e No improvement of foot deformity by operation (extensive valgus-abduction deformity).

nor by comparative terms such as improved, worsened, etc. Instead registration of deformities of the foot and knee joint observed in walking or, in cases unable to walk, in standing was used. In order to get the greatest possible objectivity the results were assessed both by the paediatrician and the operating orthopaedic surgeon. The patient material was divided into two age groups at operation, one group 2-7 years, comprising 16 patients with 24 operations, and the other 7-14 years, comprising 16 cases with 24 operations. Median observation time for the whole group was 2.1 years, for the younger age group 2.2 and for the older 2.0.

In Table 1 postoperative observations made concerning the equinus and other deformities which were usually present are summarized. Equinus was found in three feet (3 patients with diagnosis spastic diplegia), classified as poor results, all of them due to primary insufficient elongation of the tendon at operation (Table 2). One case required reoperation with another achilles tendon elongation 3 years later. The other two had a mild deformity which did not interfere with their ability to walk with shoes and as yet showed no tendency for progress. In one of these cases no equinus could be found in the supine

Table 2. Factors negatively influencing the results in cases classified as "poor" after operative treatment of equinus deformity of the foot in children with a spastic CP-syndrome

	Achilles tendon elongation	Gastrocnemius recession
Total number of procedures	48	43
Total no. of poor results (feet)	6	27
Equinus at removal of postoperative plaster after 6 weeks	3	5
Later relapse of equinus	—	22
No improvement of foot deformity (valgus-abduction)	3	1
Hyperextension of knee joint without equinus	2*	4
Hyperextension of knee joint with equinus	1	3
Reoperation due to equinus	1	16
Calcaneus deformity	—	—

* Both cases are re-operations after previous gastrocnemius recession and showed hyperextension of the knee joint before achilles tendon elongation.

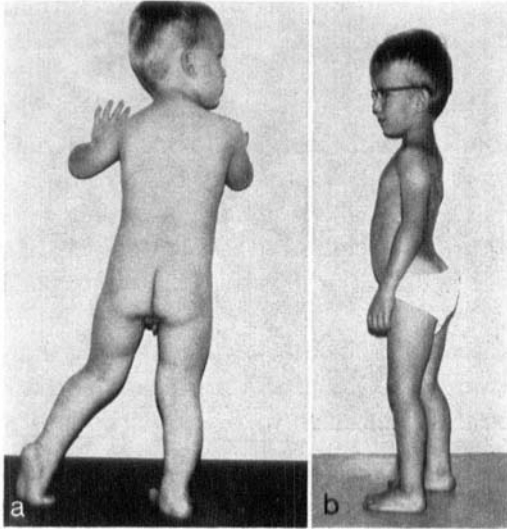


Figure 2a. 4-year-old boy with a spastic diplegia with left side dominance showing a considerable foot equinus and inward rotation of the leg in standing and walking.

Figure 2b. The same patient as in Figure 2a, 1 year and 10 months after achilles tenoplasty on the left side. In standing there is no equinus and the heel touches the floor without hyperextension of the knee. The result was, however, ranged as "poor" because in walking without shoes he showed equinus and slight hyperextension of the knee.

position or in standing, as can be seen in Figure 2B. In walking without shoes, however, he showed equinus and slight hyperextension of the knee joint which was also present preoperatively.

In three more feet (2 patients), classified as poor results, tendon elongation gave no improvement of the foot deformities which showed a "masked" equinus combined with extensive valgus of the heel and abduction of the forefoot. Both patients had a diagnosis of atactic diplegia, in one of them combined with infantile hydrocephalus. They were later treated with a triarticular subtalar arthrodesis.

Of the other 42 feet, 40 required no further surgical treatment for foot deformity during the follow-up period, and two were operated on for hallux valgus. 35 feet showed valgus deformity of slighter degree. Of the 16 feet (11 patients) previously treated insufficiently with gastrocnemius recession (Silfverskiöld's procedure), 15 showed no equinus. One was among those mentioned above as poor results due to valgus-abduction deformity. Four cases hyperextended their knee joints preoperatively. Two of them showed the same deformity postoperatively, whereas two walked without hyperextension (Table 2).

Adhesions between skin and tendon interfering with function or migration of the steelwire sutures did not occur in any case. No post-operative complications occurred.

Table 3. Results reported by different authors after operations for equinus deformity of the foot in patients with cerebral palsy

The definition "positive" covers discernments as: excellent, good, fair, improved, etc.; and "negative": poor, worse, unimproved. The significance of "positive" and "negative" is not directly comparable between different authors.

	Achilles tendon elongation*			Gastrocnemius procedured†			Re-op. for equinus
	No. of procedures	Positive results	Negative results	No. of procedures	Positive results	Negative results	
Green & McDermott (1942)	125	83	24	19 b, c	13	6	?
McCarroll & Schwartzmann (1943)	106	85	12	174 b	112	51	?
Phelps (1957)	121	29	?	59 b	6	?	?
Banks & Green (1958)	164	148	14	36 a, b, c	26	10	13
Strayer (1958)	-	-	-	23 d	18	5	?
Silver & Simon (1959)	-	-	-	110 c	105	5	?
Pollock (1962)	128	70	6	12 d	10	2	?
Hagberg, Lemperg & Lundberg (1968)	48	42	6	43 a	16	27	16

The total number of feet given in the result columns does not always correspond to the number of operated feet, due to loss of patients at follow-up and to lack of specifications.

* Controlled elongation of the achilles tendon.

† Includes (a) recession of gastrocnemius insertions from femoral condyles, (b) total or partial neurectomy of the motor branches to the gastrocnemius, (c) a combination of a and b, (d) lengthening of gastrocnemius aponeurosis.

DISCUSSION

The reason for re-adopting an achilles tendon elongation procedure was the clearly unsatisfactory results of gastrocnemius recession in our previous material: 27 relapses of equinus deformity and 16 re-operations for this reason in 43 operated limbs (Hagberg et al. 1968).

In Table 3 an attempt is made to summarize the results obtained by different authors by achilles tendon elongation in comparison with various gastrocnemius procedures. These results, though not directly comparable, may be interpreted in favour of the tendon elongation. Study of the literature on achilles tenoplasty in children with CP-syndromes gives a false interpretation of the effect if the clinical material has not been clearly classified and neurologically defined before operation. The inclusion of dystonic tetraplegic syndromes without any real spasticity can be one cause of error. Another source of error is operation of the equinus performed before flexion contractures of the knees have been released (Pollock & English 1967) or false evaluation of the strength of muscle antagonists. Thus the indication for operation must be thoroughly considered and all possible interfering factors taken into account.

In this series of 48 equinus deformities in children with a spastic CP-syndrome, a sliding Z-plasty of the achilles tendon proved to be a reliable and safe procedure. In spite of careful neuropaediatric selection of suitable cases, no improvement of the feet was obtained in three instances (2 patients) and a masked equinus and valgus-abduction deformity was the end result. This was explained by the type of CP involved viz. atactic diplegia. In a combination of a spastic and atactic syndrome the component of hypotonia and muscular insufficiency, characteristic for the latter, has an obvious tendency to dominate, especially if it is associated with infantile hydrocephalus. In patients with this severe type of CP, spastic feet with valgus-abduction deformities will obviously not be improved by tendon elongation alone, but will need additional stabilizing operation.

No differentiation was made in this series regarding the role of the two active muscular components—gastrocnemius or soleus—causing the equinus. Silver & Simon (1959) claimed that in almost all younger children, the gastrocnemius alone is responsible for the equinus whereas Keats (1965) stated that the soleus is involved in almost all contractures of the tendocalcaneus. In our opinion, selection of patients for gastrocnemius recession by Silfverskiöld's test, carried out in the

supine position, may not reflect the true functional state of the triceps surae in walking and weight-bearing. Therefore, this test can lead to erroneous selection of patients and unsatisfactory functional results. We believe, in accordance with Keats, that in most spastic CP-syndromes the whole triceps surae is responsible for the equinus.

On comparing our own results in a preceding series with gastrocnemius recession (Hagberg et al. 1968) with achilles tendon elongation (Tables 1 and 2), it was found that 27 failures in 43 procedures in the gastrocnemius group were, in 22 cases, due to recurrence of the equinus and in 5 due to insufficient correction at operation. However, in the achilles tendon group 6 failures in 48 procedures were due in 3 instances to insufficient elongation of the tendon at operation and in the other 3 to wrong indication for this operation.

In the primarily fully corrected cases of achilles tendon elongation no tendency for recurrence of the equinus was found even though usually no splints and bracing were used. This also applied to the 16 feet previously treated by gastrocnemius recession. However, the observation time in this study allows no definite statements as to the long-term results.

Achilles tendon elongation, if carried out correctly, does not diminish the power, but usually increases the strength of the triceps surae in patients with CP, as recently found by Cozen (1966). In contrast, popliteal neurectomy and gastrocnemius recession will materially affect the strength of the triceps surae (Keats 1965). Another disadvantage of gastrocnemius recession is the tendency to hyperextension of the knee which follows this procedure. The hyperextension may be accentuated by a hamstring transfer done previously or performed later (Eggers & Evans 1963, Keats 1965).

In comparing the age group 2-7 years and 7-14 years, no difference was found as regards the effect of the achilles tendon elongation on the equinus. This indicates that achilles tendon elongation may be performed at an early age when functional and development reasons demand operation and a correct diagnosis of a purely spastic CP-syndrome has been confirmed. The risk of calcaneus deformity seems very slight if the surgical method described is correctly executed in carefully selected cases.

SUMMARY

A follow-up study was made on 32 children with spastic forms of cerebral palsy in whom 48 achilles tenoplasties had been performed on an

average of 2 years earlier for equinus deformity of the foot. Spastic diplegia was present in 26 cases, five with additional ataxia; 5 had spastic hemiplegia, one of these additional ataxia; and one case had athetoid dyskinesia. The age at operation was in 24 instances between 2-7 and in 24 between 7-14 years. Mean observation time was 2.1 years, range 1-4 years. In 16 feet gastrocnemius recession had been carried out on an average 3 years previously.

The effect upon the equinus deformity, estimated during walking or weight-bearing, was clearly satisfactory in 42 instances. This was also true in those cases which had previously been inadequately treated with gastrocnemius recession. In three instances (3 patients) insufficient elongation of the tendon was the cause of persistent equinus. One of them had to be re-operated. In three other limbs (two patients) no improvement of the foot deformity, equinus-valgus-abductus, was obtained, these patients having an atactic diplegia with the characteristic hypotonic muscular insufficiency of this syndrome. These three failures must be attributed to wrong indication for operation and do not influence the merits of this operation. Calcaneus deformity never occurred.

In children with a definite and purely spastic CP-syndrome, independently of age, achilles tendon elongation in our hands proved to be a reliable and safe procedure for treatment of equinus deformity, provided the operation had been executed correctly and the patients had been selected carefully.

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