

MUSCLE FUNCTION OF TRANSPLANTED FLEXOR MUSCLES IN THE THIGH IN PERIPHERAL PARALYSIS OF EXTENSOR MUSCLES

By

KÅRE HAUG

The development of this method of operation dates back to *Nicola-doni* (1), who in 1880 suggested transplantation of tendons in the treatment of paretic muscles. The first transplantation of the biceps flexor femoris to the patella was performed by *Goldthwait* (2) in 1896. This operation was done for the relief of quadriceps femoris paralysis in residual poliomyelitis. In addition *von Eulenburg & Sonnenburg* (3) described the method in the treatment of Morbus. Little, in which the stronger flexors of the femoris caused contracture of the knee joint.

The main purpose of the operation is to make the use of the knee bandage unnecessary and to improve gait (4). But as late as 20–30 years ago the range of indications for operation was still narrow: if the patient could overcome his quadriceps gait, the operation was considered contra-indicated (5). In slight quadriceps paresis knee bandages and the like were recommended (6). It was long believed that paralysis of the gastrocnemius, *i.e.*, the muscle normally preventing recurvation of the knee, made a really successful operation impossible. Neither was transposition performed if gluteus maximus function was impaired, it being feared that it would result in a stooping carriage of the body. In recent years, however, excellent results of transpositions have been achieved even in patients with paralysis of the gluteus maximus and gastrocnemius (4).

The static equilibrium in the erect position is the key to the understanding of important problems concerning quadriceps paralysis with consequent knee joint contractures.

Normally the centre of gravity of the body passes through the knee or just in front of the knee if the subject is standing with the quadriceps relaxed (Fig. 1 a). In quadriceps paralysis the posture of the

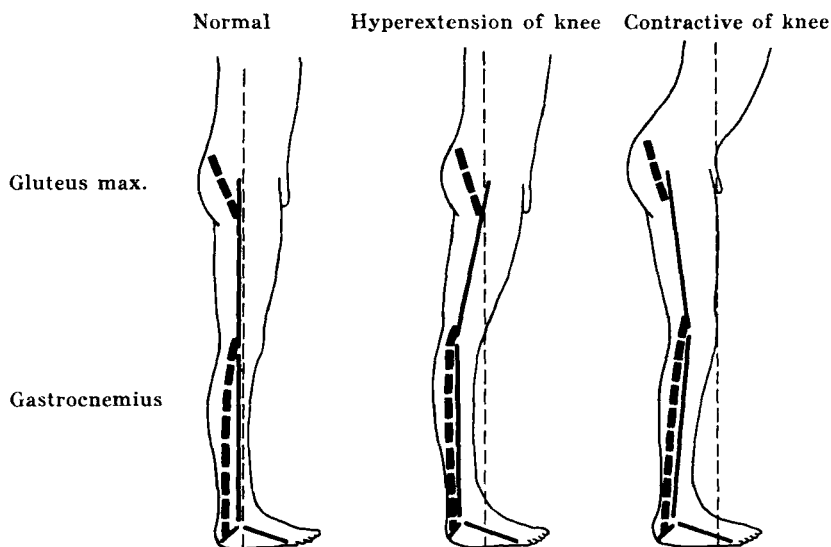


Fig. 1.

STATISTICAL EQUILIBRIUM

(interrupted line denotes axis of gravity of body)

patient is such that the axis of gravity passes through a point some distance before the knee, which is hyperextended (Fig. 1 b). Then the power of gravity is balanced against the gluteus maximus and gastrocnemius. In the presence of contracture of the knee joint, the centre of gravity of the body shifts still further forward (Fig. 1 c). This is accompanied by increased lumbar lordosis and the condition can simulate contracture of the hip joint.

In quadriceps paralysis the gait is unsteady because if the knee is loaded when flexed, it is liable to give way owing to inadequate reflex contraction of the quadriceps. The gait is slow because of the lack of acceleration of the extension of the knee (7).

The question of flexion of the knee is dependent mainly on the ratio between the strength of the transplanted thigh flexors and the hamstrings that are still intact. Modern handbooks on orthopaedics also warn against transplantation of all hamstrings (8).

The principle of the method of transplantation is the same as that originally suggested: to counteract instability and to improve joint function by reconstruction of the stretch muscles. A number of variations concerning the type and number of incisions of the skin and the choice of muscles have been recommended (9).

In the beginning only the biceps was transplanted. In *Schwartzmann & Crego's* series of 1948 this method produced lateral dislocation of the patella and consequent limitation of extension of the knee in 40 %. The dislocation was reduced by shifting the attachment on the tibular tuberosity medially or by transplanting the semitendineus to the patella.

The former belief that the 5 flexors originating from the tuber ischii must also be loosened and transplanted anteriorly so that the origin process will not be situated behind the axis of flexion of the knee joint, and that the tensor fascia lata is less suited for transposition because it is capable of a certain extension in the knee has long been abandoned (10). For it has even been shown that transposition of the tensor alone with dissection of the iliotibial tract, which has been passed like a cord through a tunnel on the anterior aspect of the quadriceps and fastened to the tibial tuberosity gives good extension of the knee and a much better gait (11).

It has long been realized that it is necessary to loosen the tendon and the muscle as high up in the thigh as possible without, however, injuring the nerves or vessels supplying the muscle. This gives the straightest possible course of the transplanted muscle. It is also important to fasten the tendon directly to bone in the patella and, if the tendon is long enough, also to the tibial tuberosity.

It is not necessary to correct any contracture of the knee before transplantation of the muscle tendon in contrast to what was formerly believed (6). It is the increased tonus of the flexors of the knees that tends to cause contractures. It is therefore sufficient to straighten out the knee during operation when the flexors have been loosened from their attachments.

At the Kysthospitalet ved Stavern, the following operation method has been used (12):

1. Bylow-Hansen's incision of the skin which consists of a medial and lateral longitudinal incision of the thigh. Both incisions are begun in the upper part of the thigh and extend downwards dorsally, then swing anteriorly, the medial incision towards the pes anserinus, the lateral over the fibular head towards the tibial tuberosity. This provides a good approach to the thigh muscles and their attachments. In addition, the lateral incision enables exposure of the patella, the patellar ligaments and the tibial tuberosity.

2. Each muscle is dissected separately high up in the thigh and passed through preformed subcutaneous channels subcutaneously with as straight a course as possible towards the patella.

3. The tendons are fastened intra-osseally with strong sutures to the patella and tibial tuberosity. (As a rule, the biceps reaches only to the lower border of the patella).

4. Sometimes the iliotibial tract is rotated 180° about its axis and attached to the patella so that it will cover the transplanted hamstrings.

5. Any contracture of the knee is corrected during the operation and the knee is fixed in the corrected position in plaster bandage for 8 weeks after operation.

Active muscle traction of the patella is started early after the operation. Active exercise of the transplanted muscles is an important part of treatment.

AUTHOR'S SERIES

The present series consisted of patients operated at the Kysthospitalet ved Stavern during the last 10 years with transposition of the flexors of the thigh because of quadriceps-femoris paralysis or paresis in residual poliomyelitis.

A total of 23 operations were performed on 20 patients, 3 of the patients having been operated upon bilaterally. 7 were excluded: 5 because they had been followed up for less than 6 months and 2 because they had moved so far away. This left 15 operations on 13 patients.

The after-investigation consisted of simple, clinical examinations. All the patients were re-examined by the author.

Voluntary contraction of the transported muscles could be palpated in all of the cases except one. In that case the biceps had shown "marked fatty degeneration" already during the operation.

A measure of the power of contraction of the transported muscles can be obtained by reading the number of degrees the patient is able to extend the loosely hanging leg.

Table 1 shows the pre-operative range of extension of the knee, which muscles are transplanted and their state (healthy or degenerated), and the extension of the knee measured at the after-examination. It is noteworthy that in one case, in which the biceps was paralyzed, the semitendinosus alone could not produce extension. In another case, in which only the biceps was transplanted, the operation had only had weak effect on extension. Without including the biceps, 2 or 3 of the medial flexors can give satisfactory extension.

An important question is whether any change occurs with time in the range of contraction of the transplanted muscles. In the 9 cases, in

TABLE 1

Preoperative test		Transposed muscles: paralyzed muscles						Post-operative test
Op. nr.	Quad- riceps	Biceps femoris.	Gracilis	Semi- tendin.	Semimem- bran.	Sarto- rius	Tractus ilio-tibialis	Extension of knee 0-90 degrees
1	0		(+)	(+)			+	45
2	0			+	+	+		70
3	0	+	+	(+)		+		90
4	(+)	(+)		+			+	0
5	(+)	+	+	(+)		+	(+)	20(50)
6	0	+	+				+	65
7	0	+	(+)			(+)	+	60
8	0	+					+	30
9	0	(+)		+				45
10	+		+			+		65
11	(+)	+	(+)			+		45
12	0	+				+	+	90
13	0	+	(+)	+			+	65
14	+	(+)	(+)	(+)		+		60
15	0	+	+	(+)		+		80

TABLE 2

Postoperative function of knee as judged by range of extension.

Op. nr.	1. measurement	2. measurement	Difference
1	50 degrees	45 degrees	— 5 degrees
2	90 "	70 "	—20 "
3	80 "	90 "	+10 "
4	55 "	50 "	— 5 "
5	55 "	65 "	+10 "
6	45 "	60 "	+15 "
7	40 "	30 "	—10 "
8	60 "	65 "	+ 5 "
9	75 "	65 "	—10 "

which the extension of the knee was measured on at least 2 occasions, it was increased in 4 and decreased in 5. (Table 2, Fig. 2).

It is uncertain whether the changed functional conditions of the transplanted muscles have any effect on their functional capacity. It was tested by watching the patient when climbing stairs because then

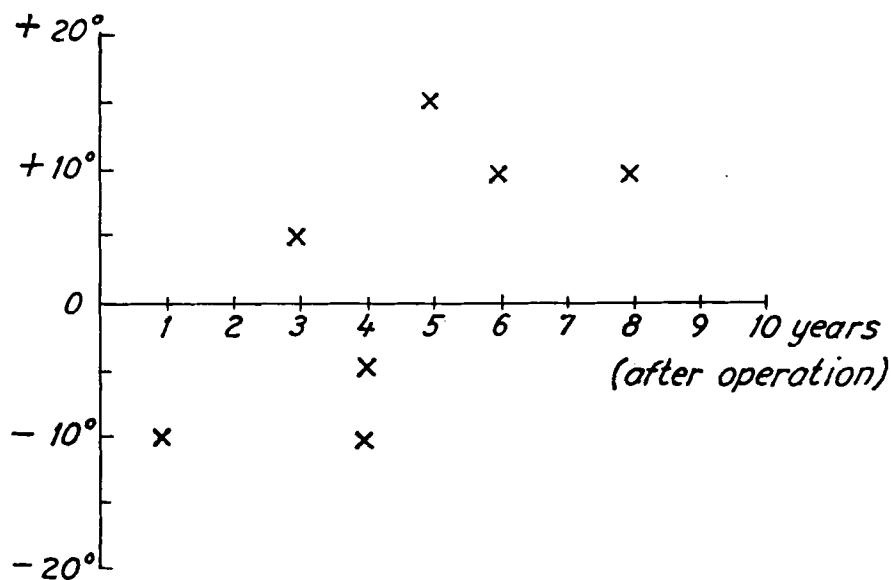


Fig. 2.

Positive and negative changes in extension of knee joint and time of measurement.

TABLE 3
Postoperative improvements.

Op. nr.	Increased stability of knee	Manage without bandage	Manage without stick (crutches)	Gait improved	Less marked lumbar lordosis	Less marked contracture of knee joint
1	×			×	×	10-0 degrees
2	×			×	×	30-0 "
3	×		×	×	×	40-0 "
4						10-0 "
5	×			×	×	
6	×	×	×	×		10-0 "
7	×	×	×	×		5-0 "
8	×	×		×		15-0 "
9	×	×		×		
10	×			×	×	15-5 "
11	×	×		×		
12	×	×	×	×		25-0 "
13	×			×		25-8 "
14	×	×		×	×	20-10 "
15	×			×		25-0 "

the slightly flexed knee must be extended several times in succession while weight bearing. In 8 occasions the results of the test were satisfactory and in all of them the patients reported that it was easier to walk upstairs after the operation and that this improvement had been permanent.

Table III gives a survey of the post-operative improvements. All, except one, reported a feeling of improved stability of the knee, *i.e.*, after 14 of 15 operations. In 8 cases the patients were able to manage without a supporting bandage or crutches. The series included 12 contractures of the knee which disappeared completely or partially after the operation.

A decrease of the valgus of the knee from 20 to 5 degrees on one leg and from 10 to 5 on the other was noted in a boy who had been operated upon at 10 and 11 years of age. In a girl operated upon at 12 years the valgus decreased from 15 to 10 degrees.

The side effects of transposition are relatively slight. Flexion of the knee becomes slightly weaker but this is of little functional importance. It is known that good function of the gastrocnemius is necessary for active flexion of the knee after operation. Satisfactory function was found after 10 of 11 operations. In the case of lacking knee flexion the gastrocnemius before operation was weak (+3) and the re-examination took place only half a year after the operation. It was noteworthy that a boy with impaired function of the gastrocnemius bilaterally was nevertheless able to manage without crutches and supporting bandages and is now able to walk with slight recurvation of the knees for more than 1 kilometer at a time. Recurvation of about 5 degrees during weight bearing of the leg was noted in 4 cases. In one case in a girl it was 30 degrees. She was operated upon at 12 years and then had a flexion contracture of 25 degrees. The medial hamstrings were very weak and were not able to withstand the pull of the strong transported muscles. But the patient is not troubled by this residual contracture and has a normal gait. In another case, in which all the hamstrings were transplanted and the gastrocnemius was weak, a 30 degree contracture disappeared but, strangely enough, no recurvation developed. The above mentioned lateral dislocation of the patella was not seen in the present material. It occurred in a patient who had been operated upon elsewhere and disappeared after transposition of the medial hamstrings.

Stiffness of the knee was reported by 6 patients, but in 5 it was only slight. One patient reported slight weakness of the knee. This weakness

appeared after he had walked about 100 meters. Only one complained of transient pain in the knee after the operation.

One patient had no benefit from the operation apart from elimination of a 10 degree flexor contracture. That patient had severely fatty degeneration of the biceps and a healthy semitendinosus as the only available muscle for transposition.

In one case a satisfactory reconstruction of the extensors was spoiled by a supracondylar fracture of the femur. In another the extensor function was severely impaired on forced passive flexion of the knee during parturition. After later reconstruction of the ruptured patella ligament, extension was again good.

TABLE 4

Results of transposition of muscles for quadriceps paralysis in residual poliomyelitis.

	Excellent	Good	Fair	Satisfac- tory	Bad	Cases
(4) Schwartzmann and Crego (1948)	67 %	7 %	13 %	87 %	13 %	134
(13) Noe, Ziegler, Herrera (1949)				93 %	7 %	27
(14) Canadell-Carafi, Barraquer-Bordas (1955)				96 %	4 %	56
Kysthospitalet ved Stavern (1960)		67 %	24 %	94 %	6 %	15

Excellent: 1) normal strength of active extension; 2) no recurvation; 3) manage without bandage; 4) no lateral displacement of patella; 5) knee stable when walking.

Good: 1) active extension 45-90 degrees (135-180°); 2) slight or no recurvation; 3), 4), 5) as for excellent.

Fair: 1) active extension 5-45 degrees (95-135°); 2) slight or moderate recurvation; 3), 4), 5) as for excellent.

Bad: 1) no extension; 2) severe, painful and disturbing recurvation; 3) needs bandage; 4) lateral displacement of patella; 5) unstable when walking.

RESULTS OF AFTER-EXAMINATION

To facilitate comparison, the results are given in percentages despite the fact that the material was so small and heterogeneous.

The cases are graded in accordance with the recommendations of *Schwartzmann & Crego* (1948).

Good agreement was found between the objective findings and the

answers given by the patients concerning the improvement after the operation. Only one patient reported that the condition was the same as before the operation.

DISCUSSION

It is clear from Table 1 that the range of indications for transplantation of the thigh flexors in paralysis of the quadriceps in residual poliomyelitis, was wide, since even muscles with fatty degeneration and weak muscles were often used. The results of the operation must therefore be evaluated in the light of the wide range of indications.

That the results were so good must be ascribed, above all, to the operation method used. It is important that the large incision of the skin enables evaluation of the quality of the muscles and their course after transposition. Correction of knee contractures before operation can, in our opinion, weaken the thigh flexors because they are then overstretched. It is therefore advantageous to correct contractures during the operation after the first thigh flexor to be transplanted has been loosened from its attachments.

It is perhaps possible with Yount's technique to improve extension of the knee still more if the tensor fascia lata is good. According to that method the part of the gluteus maximus that is inserted into the ilio-tibial tract as well as tensor is used. We have no experience with this method.

As mentioned previously, contracture of the knee joint can result in increased lumbar lordosis (Fig. 1 c). Conversely, it may be assumed that an elimination of the contracture of the knee will result in a correction of lumbar lordosis. This point did not receive sufficient attention before operation. Nevertheless, an improvement of the lumbar lordosis was often seen in those cases in which contracture had been eliminated. (Table 3).

Valgus of the knee decreased after 3 operations. In one case where only the biceps had been transplanted and not the iliotibial tract, the valgus decreased less than expected (from 15 to 10 degrees). It is therefore possible that a tense tractus iliotibialis is equally important as a contracted biceps as a cause of valgus. Otherwise the biceps is regarded as an important factor in the cause of valgus, knee-flexion and rotation of the tibia in quadriceps paralysis (15).

Although recurvation sometimes occurs as a consequence of muscle transplantation, this risk is, as shown, not so great, and therefore one

should not attach too much importance to it in the evaluation of indications for operation. Neither does recurvation seem to disturb the patient at all.

CONCLUSIONS

The present after-examination of patients operated upon with transplantation of the flexor muscles of the thigh because of quadriceps-paralysis and paresis in residual poliomyelitis have shown that:

in this series as well as in those earlier published this operation prove to be of great value;

it is unnecessary to correct any knee joint contracture before operation;

it is probable that knee joint contracture will result in increased lumbar lordosis;

increased valgus of the knee can decrease after transposition of the biceps and iliotibial tract; and

forced passive flexion of the knee can severely impair function of the transplanted muscles.

RESUME

Il est donné un aperçu des vues antérieures sur les indications de la transposition des tenseurs de la cuisse dans les cas de paralysie du quadriceps due à la poliomyélite. La base théorique du principe la méthode de transposition a été cherchée dans l'équilibre statique du corps. Des détails importants de l'opération sont relevés et la méthode de l'opération appliquée par l'hôpital Kysthospitalet de Stavern est décrite.

Les observations recueillies durant une période de 10 ans se rapportent à 20 malades chez lesquels il a été pratiqué 23 opérations. 13 malades, représentant 15 opérations, ont été réexaminés par l'auteur qui leur a fait subir un simple examen clinique.

Dans 4 cas on a constaté que le pouvoir de contraction était accru et dans 5 cas diminué durant la période de l'observation. Les conditions modifiées des fonctions des muscles transposés ne paraissent pas influencer sur leur capacité de travail que l'on a cherché à apprécier par des essais sur des escaliers.

Les améliorations post-opératoires et les conséquences délétères qui peuvent suivre l'opération sont examinées en détail. Il est mentionné en

particulier une réduction observée de la valgidité du genou et une diminution de la lordose lombaire après l'opération.

Les résultats obtenus s'établissent au niveau de ceux publiés antérieurement puisque 94 % étaient satisfaisants. Dans un cas l'opération n'a eu aucune utilité sauf qu'une contracture de 10 degrés de l'articulation du genou a été éliminée.

Il est mentionné 2 cas où le bon résultat de la transposition des muscles a été anéanti, l'un par une fracture supra-condyloire du fémur, l'autre par une flexion passive forcée au cours d'un accouchement. Dans une reconstruction ultérieure du ligament patellaire rompu, l'extension a de nouveau été améliorée.

ZUSAMMENFASSUNG

Eine Übersicht von früheren Auffassungen der Indikationsstellung für die Transposition von Oberschenkelbeugern bei der poliomyelitischen Lähmung des Quadriceps wird gegeben. Die theoretische Grundlage für das Prinzip der Transposition wird im statischen Gleichgewicht des Körpers gesucht. Wichtige Einzelheiten der Operation werden hervorgehoben und die Operationsmethode, welche man am Kysthospita! Stavern verwendet, wird beschrieben.

Das Material, welches von einer Zehnjahrsperiode gesammelt wurde, besteht aus 20 Patienten und es wurden 23 Operationen ausgeführt. 13 Patienten mit insgesamt 15 Operationen wurden vom Verfasser mit einfachen, klinischen Mitteln untersucht.

In 4 Fällen hat man eine Zunahme, und in 5 Fällen eine Abnahme der Kontraktionskraft während der Beobachtungszeit gefunden.

Die veränderten Funktionsbedingungen für die transponierten Muskeln scheinen nicht auf ihre Arbeitsfähigkeit einzuwirken, was mittels der Treppenprobe zu beurteilen versucht wurde.

Die postoperativen Verbesserungen und deletären Folgen werden bis ins Einzelne durchgegangen. Besonders wird die postoperative Abnahme der Valgität im Knie und der lumballordose besprochen.

Die erreichten Resultate stehen auf gleicher Höhe mit vorhergehenden Veröffentlichungen, da 94 % zufriedenstellend waren. In einem Fall war die Operation nutzlos, abgesehen davon, dass eine Kniegelenkskontraktur von 10° beseitigt wurde.

Man erwähnt zwei Fälle, in denen das gute Ergebnis der Muskeltransponierung ruiniert wurde, in einem Fall durch eine suprakondyläre Fraktur, in dem anderen durch übermässige, passive Beugung während

einer Geburt. Mittels einer späteren Wiederherstellung des lig. patellae wurde die Extension neuerlich gebessert.

REFERENCES

1. *Nicoladoni, C.*: Ueber Sehnentransplantation. Aus d. chir. Sect. d. 54 Versammlung Deutsch. Naturforscher u. Artze in Salzburg 1880.
2. *Goldthwait, J. E.*: Tendon Transplantation in the Treatment of Deformities Resulting from Infantile Paralysis. Boston Med. and Surg. J. CXXXIII, 447, 1895.
3. *Hoffa, Albert*: Lehrbuch der Orth. Chir., Stuttgart 1905, s. 144.
4. *Schwartzmann & Crego*: Hamstring-tendon transplantation for the relief of quadriceps femoris paralysis. J. Bone Surg., 30A: 514, 1948.
5. *Crego & Fischer*: Transplantation of biceps for the relief of quadriceps femoris paralysis in residual poliomyelitis. J. Bone and Joint Surg. XIII, 3: 515, 1931.
6. *Debrunner, H.*: Die Behandlung der Quadriceps Laehmung. Z. Orthop., 70: 164, 1940.
7. *Steindler, A.*: Kinesiology of the Human Body. Publisher: Charles Thomas, p. 356-357.
8. *Lange, M.*: Orthopaedisch-chirurgische Operationslehre, München 1951.
9. *Bier-Braun-Kümmel*: Chirurgische Operationslehre, bind IV, 459-462, 1933.
10. *Silverskiöld*: Ueber Quadricepsplastik. Verhandlungen der Deutschen Orthopaedischen Gesellschaft, 16. Kongress 1921.
11. *Josserand*: Transplantations du tenseur du fascia lata pour une paralysie du quadriceps. Lyon chir., 31: 204, 1934.
12. *Stören, H.*: Some Experiences of Transposition of the Hamstrings in Paralysis after anterior Poliomyelitis. Act. Orthop. Scand. XXVI, 4: 283, 1957.
13. *Noe, M., Ziegler, G. & Herrera, S.*: Late result of tendon transplantations to quadriceps. Revista Medica de Chile, Santiago. 76/11: 674-679, 1948.
14. *Canadell-Carafi, J. & Barraquer-Bordas, L.*: Resultados del la plastic du quadriceps dans la poliomyelite. Acta Orthop. Belg., 21/4: 241-251, 1955.
15. *Yount, C. C.*: An Operation to improve Function in Quadriceps Paralysis. J. Bone and Joint Surg., 20: 314, 1938.