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Herbert Capsuloplasty and Burnei Tenomyoplasty for the Correction of Genu Flexum in Cerebral Palsy, Arthrogryposis and Posttraumatic

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Rezumat

Capsuloplastia Herbert și tenomioplastia Burnei în corectarea genu flexum-ului din paraliziile cerebrale, artrogipoza și posttraumatic

Introducere: Cinematica mersului a scos în evidență necesitatea unor mişcări complexe ale genunchiului sincronizate cu anumite poziții ale şoldului şi gleznei, atât în faza de oscilație, cât şi în faza de sprijin unilateral. Afectarea acestor poziții, mai ales în paraliziile cerebrale şi artrogripoză, împietează mersul, uneori până la limitarea acestuia la distanțe foarte scurte şi adesea au ca efect final imposibilitatea mersului. Flexia genunchiului între 0-30 grade permite mersul normal. Copii care au limitată extensia gambei între 10 şi 30 de grade, mai ales în paraliziile cerebrale, au o poziție compatibilă cu mersul. Mersul este unul dificil şi acesta este considerat tipic pentru acest grad de limitare, numit și "mersul cercetașului".
Scop: Lucrarea a fost concepută pentru a readuce în discuție și actualitate utilitatea capsuloplastiei genunchiului concepută de Herbert în 1938, introdusă în România de Cl. Baciu în 1956, și tenomioplastiei distale a ischiogambierilor mediali tip Burnei, concepută în 1993.
Material și metodă: Capsuloplastia Herbert, deși a fost descrisă inițial pentru a fi utilizată în alte afecțiuni decât cele spastice și artrogripotice, a devenit în timp, o operație apreciată de medicii practicieni ca fiind foarte utilă în genu flexum spastic cu limitarea extensiei între 15 și 30 de grade. Secționarea ligamentului încrucișat posterior la copiii mai mici de 10 ani induce adesea un genu recurvatum sau instabilitate articulară. Pentru a evita aceste inconveniente, în decursul anilor s-a renunțat la acest timp operator și am recurs la relaxarea genunchiului spastic, mai rar în cel artrogripotic, prin tenomioplastia Burnei. Cele două operații efectuate în același timp au efect sinergic și complementar.
Rezultate: Un genunchi cu limitarea extensiei cuprinsă între 30 și 60 de grade operat numai prin capsuloplastie Herbert permite o redresare parțială a genu flexum-ului. Această redresare parțială este limitată de ligamentul încrucișat posterior, contractura cu retracția și scurtarea ischiogambierilor și "webbing-ul" sistemului vascular. Tenomioplastia Burnei aplicată solitar are efecte favorabile în genu flexum cu limitarea flexiei genunchiului până la 30 de grade. Cele mai bune rezultate se pot obține atunci când intervențiile Herbert și Burnei se efectuează concomitent la copii cu genu flexum cu limitarea extensiei între 30 și 60 de grade.
Concluzii: Asocierea capsuloplastiei Herbert cu tenomioplastia Burnei permite redresarea poziției rigide a genunchiului și reluarea mersului cu sau fără sprijin. De asemenea se evită evoluția spre un genu flexum mai mare de 60 de grade ce necesită osteotomie. Leziunile de condroliză ce apar în urma tentației forțate de redresare a poziției de genu flexum, atunci când bolnavii au rigiditate între 30-60 de grade și se face

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operația Herbert, sunt evitate. Nu în ultimul rând este diminuat semnificativ riscul apariției subluxațiilor și luxațiilor de genunchi.

Cuvinte cheie: paralizie cerebrală, artrogripoză, genu flexum, flexia genunchiului, tenomioplastie, ischiogambieri distali, capsuloplastie, limită mișcare genunchi

Abstract

Introduction: Studies of gait dynamics revealed the complex motions that the knee must undergo in sync with the hip and ankle, in both the swing and support phase of walking. If these motions are restricted, usually as a consequence of cerebral palsy or arthrogryposis, normal gait is hindered; the patient may be able to walk for very short distances or, eventually, not at all. Children with knee extension limited by 10 - 30 degrees, especially those with cerebral palsy, exhibit a stance compatible with walking. Walking is difficult and the gait pattern, "crouch gait", is considered typical for this degree of limitation.

Aim: This paper is meant as an update regarding the usefulness of Herbert knee capsuloplasty, conceived in 1938 and introduced in Romania in 1956 by Clement Baciu, and Burnei distal medial hamstring tenomyoplasty, invented in 1993.

Materials and methods: Herbert knee capsuloplasty, although initially intended for ailments other than spasticity or arthrogryposis, became known, in time, as a useful operation for spastic genu flexum with a 15 to 30 degree limitation of extension. Severing the posterior cruciate ligament (PCL) in children less than 10 years old often results in genu recurvatum or joint instability. In order to avoid these complications, PCL transection has been phased out and our clinic started to use, preferentially for spastic genu flexum rather than arthrogryposis, the Burnei tenomyoplasty. When applied in the same operative session, the two techniques complement each other and act in synergy.

Results: Herbert capsuloplasty can achieve only partial correction of genu flexum ranging between 30 and 60 degrees of extension deficit. Full extension is opposed by the PCL, contracture of the hamstrings and vascular retraction. Burnei tenomyoplasty used by itself is useful for genu flexum with less than 30 degrees of extension deficit. For children with 30 to 60 degrees of knee extension deficit, combining the Herbert and Burnei procedures achieves the best results.

Conclusions: The simultaneous application of Herbert capsuloplasty and Burnei tenomyoplasty allows for the correction of stiff genu flexum and enables the patient to resume walking, with or without support. This course of treatment also avoids the progression of genu flexum beyond 60 degrees, which would require an osteotomy. This combined procedure avoids the cartilage lesions which may develop when patients with 30 - 60 degree genu flexum undergo Herbert capsuloplasty alone. Not in the least, the risk of postoperative knee dislocation is significantly reduced.

Key words: cerebral palsy, arthrogryposis, genu flexum, knee flexion, distal hamstrings, tenomyoplasty, capsuloplasty, knee ROM

Introduction

Children and teenagers with cerebral palsy exhibit muscular contractures and tendon retractions, characteristically affecting the hip flexors (coxa flexa), the hamstrings (genu flexum) and the triceps surae (pes equinus). In cerebral palsy, the hamstrings may be overactive and contract inappropriately during stance phase, which limits the normal extension of the knee. Without surgical correction, the bones of the joint also become deformed as the child grows, which, along with the shortening of the muscle-tendon unit, further increases knee flexion during stance phase (1).

No statistics could be found in the literature for the prevalence of genu flexum with extension deficit between 30 and 60 degrees. In our clinic's statistic, covering the last 20 years, 40 % of patients with spastic diplegia had genu flexum. Of these, only 8 % had an extension deficit between 30 and 60 degrees.

One study (2) has found that flexed knee patterns and crouch gait are more prevalent in older children and adolescents.

Several techniques have been described for the surgical correction of genu flexum, such as: „Z" lengthening of the hamstrings, reinsertion of the hamstrings on the femoral condyles (Eggers I), transection of the patellar retinacula (Eggers II), gastrocnemius neurectomy or fractional hamstring lengthening (3).

Some authors have extended the indication for biceps femoris and semitendinosus tendon transfer to the patella (generally used for paralysis of the quadriceps) to genu flexum. However, this intervention often results in a stiff extended knee, which makes walking very difficult.

Residual genu flexum, exhibiting hamstring contracture and retraction, can be associated with bone tumors situated around the knee. This complication is more common in patients that underwent en bloc resection and modular prosthesis implantation, especially in children over 7 years old and adolescents, and in patients that received an expanding prosthesis in order to maintain limb length equality when a growth plate had been resected. In such cases, correction of genu flexum is done progressively, using physical therapy, in order to avoid elongation injury to the sciatic and tibial nerves (4).

Our experience spanning 10 years has proven that associating Herbert knee capsuloplasty with Burnei medial distal hamstring tenomyoplasty for the correction of spastic genu flexum yields good outcomes. Children operated in this way have improved knee stance and gait kinematics, in both the swing and stance phase.

Materials and Methods

Historically, the first knee capsule relaxation was performed in 1921 by Putti, who incised the capsule through a midline approach in the popliteal fossa.

Wilson performed capsuloplasties by detaching the capsule along with the periosteum through a combined posterolateral and posteromedial approach.

Herbert, in 1938, started performing capsuloplasties through a single posterolateral incision (5). In 1953, his technique was introduced in Romania by Clement Baciu (6).

Operative technique

Herbert capsuloplasty

The approach is made through a longitudinal 20 cm incision on the lateral margin of the biceps femoris, which can be extended if medial hamstring tenomyoplasty is to be performed through the same incision. The incision must be long enough to allow identification of the semitendinosus tendon-muscle junction.

- The femoral nerve, which runs along the medial edge of the biceps femoris, is identified and isolated. The iliotibial tract of Floru (7) is cut transversally, in order to release tension and to allow the periosteum of the distal lateral femur to be incised longitudinally.
- A "Z" lengthening is performed on the biceps femoris tendon.
- The lateral head of the gastrocnemius is exposed and its insertion on the condyle is severed; the capsule may be opened at this time.
- An assistant holds the knee in 60 degrees of flexion while the surgeon incises the capsule on the lateral side of the femur, opening the joint at the level of the joint line. The periosteum is stripped off the posterior surface of the distal femoral metaphysis, down to the more resilient femoral insertion of the capsule, using a sharp periosteal elevator. By levering back the aforementioned elevator and by inserting a blunt elevator into the joint, the capsular insertion is fully exposed (*Fig. 1*).
- The proximal insertion of the capsule is stripped from the femur, first above the lateral condyle, then the medial.
- After stripping, the periosteum and capsule must be contiguous and without lacerations (*Fig. 2*). If knee flexion is impeded, the posterior cruciate ligament may be cut, as in Herbert's original procedure.
- In cases with severe and stiff genu flexum, the medial hamstrings are often retracted and hinder full extension of the knee.
- In order to avoid recurrence and to facilitate walking, we perform during the same operation a medial hamstring tenomyoplasty.

Burnei tenomyoplasty

In our clinic, before the development of this technique, medial and lateral hamstring retraction had been treated using

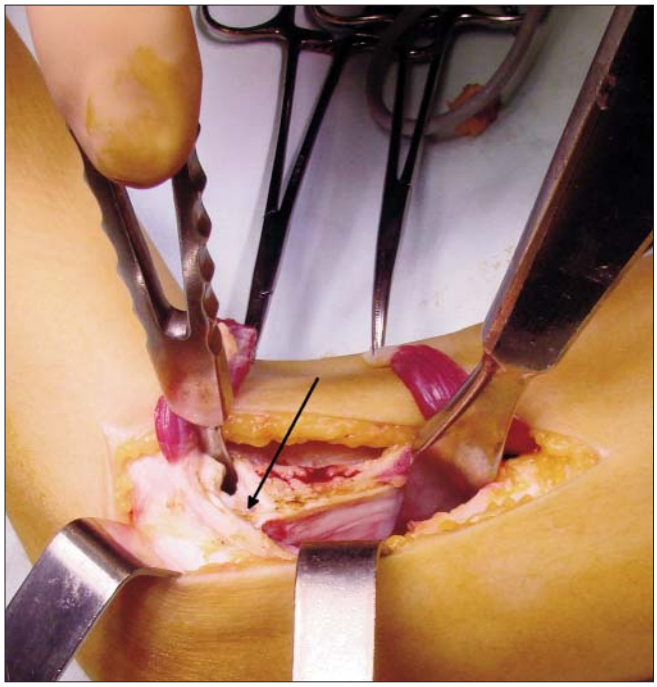

Figure 1. *After stripping the periosteum off the posterior face of the distal femoral metaphysis, the femoral insertion of the knee capsule (arrow) is exposed by levering back the posterior joint capsule and periosteum*

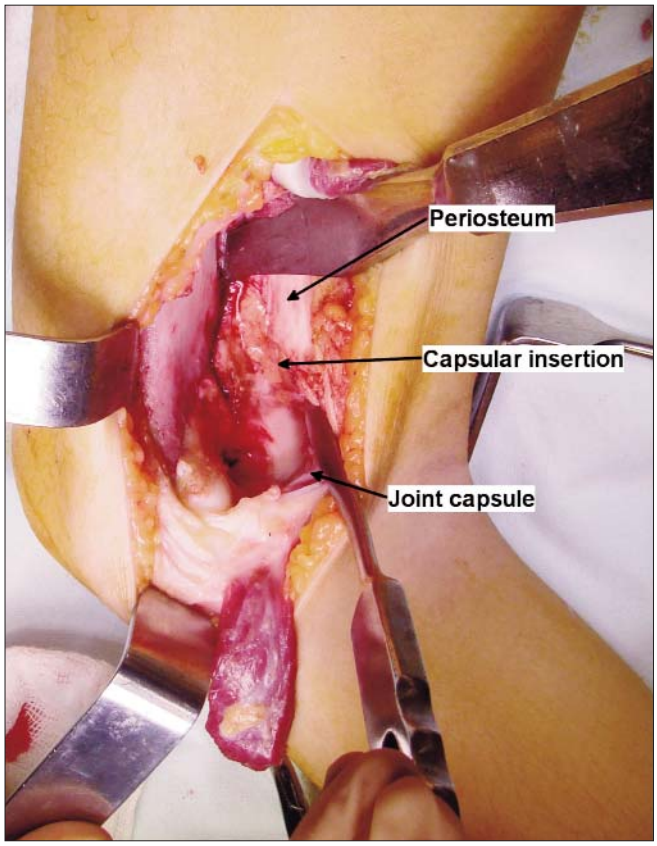

Figure 2. *The periosteum and posterior capsular insertion are stripped off the distal femoral metaphysis*

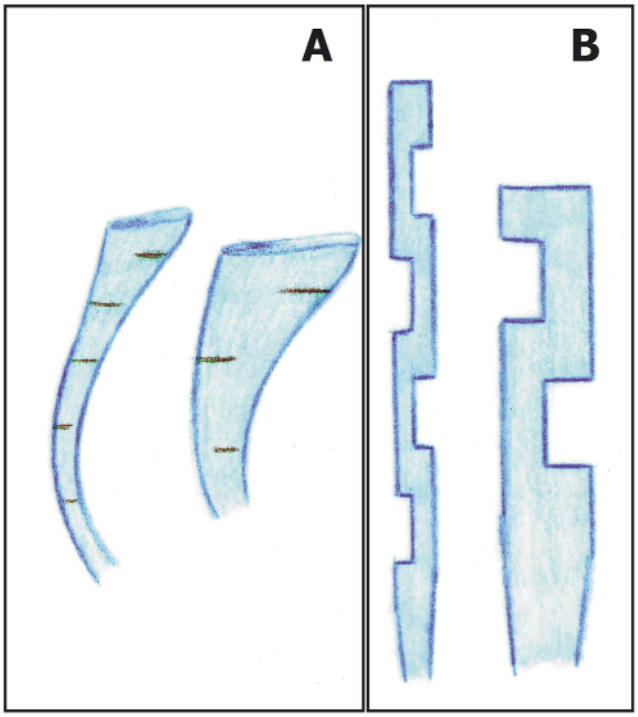

Figure 3. *Fractional lengthening (schematic) A. The incisions are made 2-3 cm apart, depending on the length of the tendon. B. Ladder-like aspect after the tendons are stretched by extending the knee*

fractional lengthening (*Fig. 3*). Follow-up of these cases revealed a significant decrease of flexion, with instances of ankylosis in extension. In all cases where individual evolution mandated a second surgical intervention, the hamstring tendons were found to be abnormally thin, with some instances of total rupture on the medial side.

Such unfavourable results prompted the development of the Burnei technique for medial hamstring distal tenomyoplasty.

Step 1 - Through the same incision, the subcutaneous layer is dissected, exposing the semitendinosus and semimembranosus. The incision should allow the identification of the semitendinosus muscle-tendon junction (*Fig. 4*);

Step 2 - The semitendinosus tendon is cut proximally, leaving some 2 cm of tendon attached to the muscle body (*Fig. 5*).

Step 3 - The proximal end of the tendon is tied with a Cuneo suture. A gap is made in the belly of the semimembranosus and the proximal end of the semitendinosus is placed within. The ends of the suture threads are fixed to the tendon of the semimembranosus (*Fig. 6*).

Step 4 - The semimembranosus tendon is cut at its distal insertion (*Fig. 7*).

Step 5 - A gap is made in the tendon of the semimembranosus and the semitendinosus tendon is passed through. The end of the semimembranosus tendon is wrapped around the semitendinosus tendon and the two are sutured together (*Fig. 8*). With this, the posterior relaxation of the knee is complete and the joint can achieve full extension.

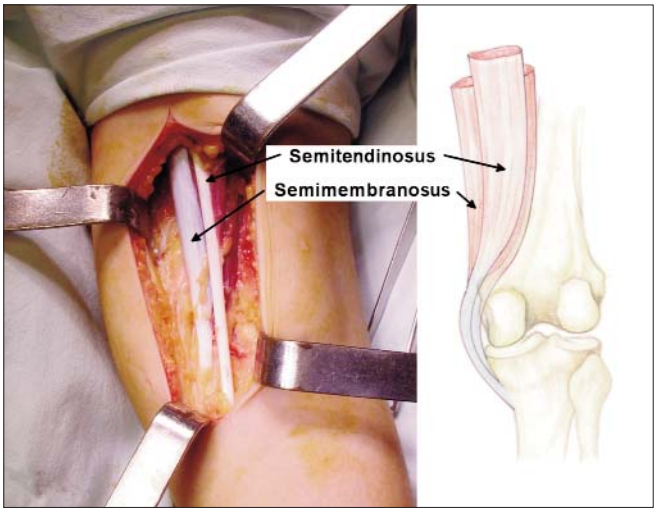

Figure 4. *Burnei tenomyoplasty - Step 1. Exposing the medial distal hamstring tendons*

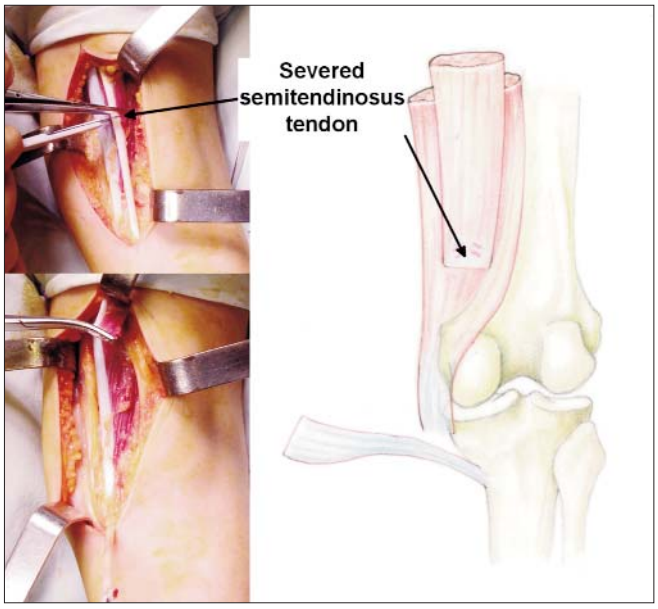

Figure 5. *Burnei tenomyoplasty - Step 2. The semitendinosus tendon is cut at the tendon-muscle junction (upper left). The semitendinosus tendon is pulled distally (lower left)*

Step 6 (optional) - If the tendon ends in step 5 cannot be sutured without tension, they should be joined using synthetic mesh wrapped around the two tendons (*Fig. 9*).

Relevant cases

Case 1. Genu flexum in cerebral palsy

The Burnei medial hamstring tenomyoplasty was used on a 10 year old patient suffering from spastic quadriplegia, bilateral genu flexum and pes equinus.

Clinically, passive knee extension was limited by 50 degrees. During gait, the knees were flexed 50 degrees in

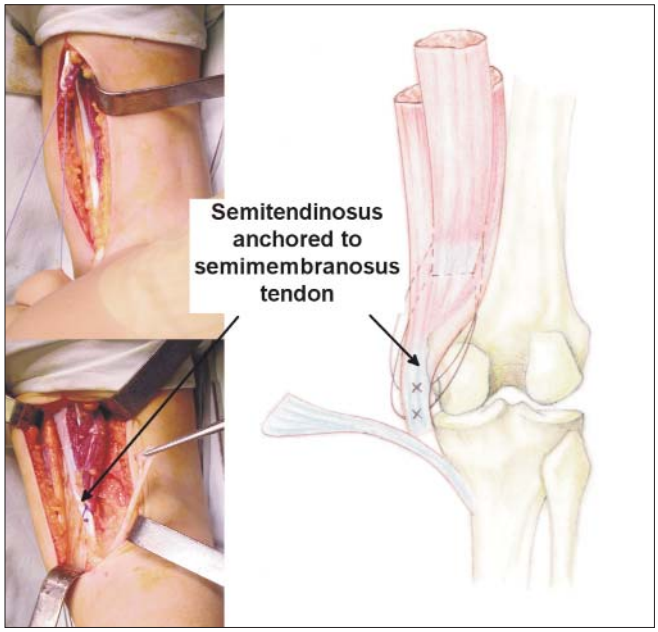

Figure 6. *Burnei tenomyoplasty - Step 3. The proximal cut end of the semitendinosus is anchored with sutures, in order for it to be implanted into the semimembranosus. The semitendinosus is inserted into a gap made in the semimembranosus and the sutures are tied distally to the semimembranosus tendon, 2 cm proximal to the insertion*

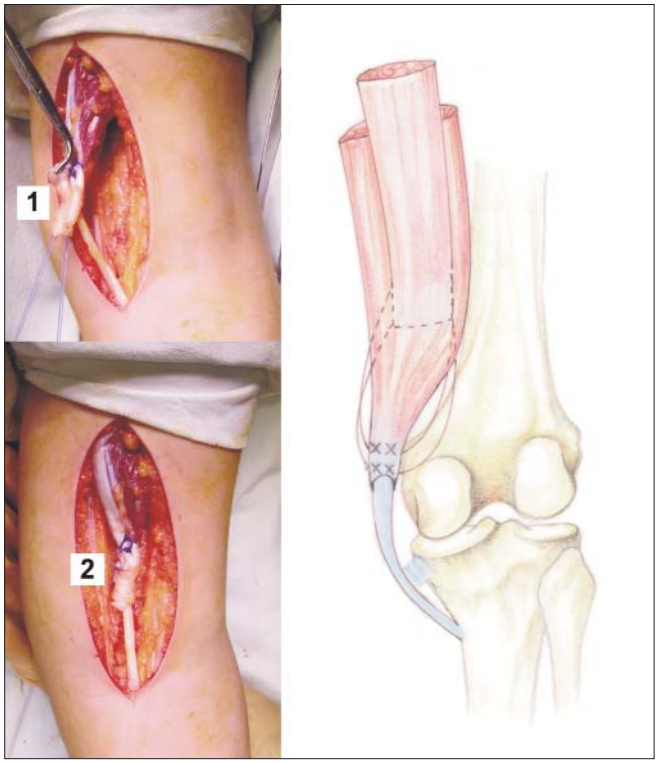

Figure 8. *Burnei tenomyoplasty - Step 5. The semitendinosus tendon is passed through a gap in the semimembranosus tendon (1); the latter is wrapped around the semitendinosus tendon (2)*

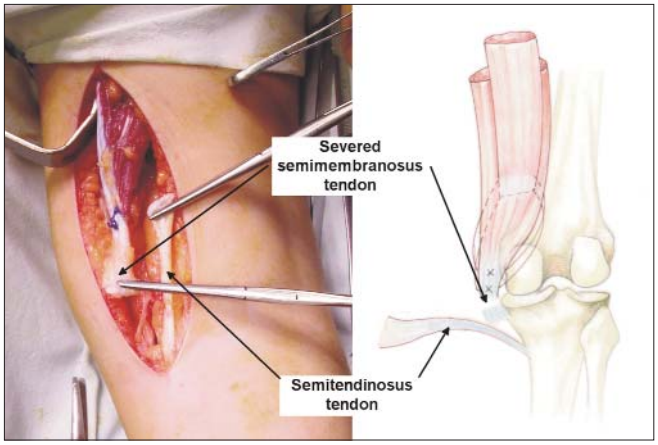

Figure 7. *Burnei tenomyoplasty - Step 4. The semimembranosus tendon is cut distally, close to its insertion*

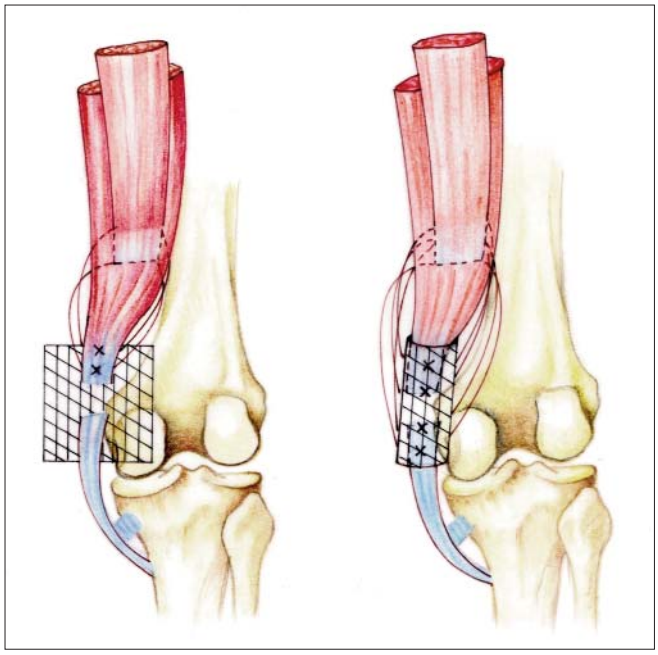

Figure 9. *Burnei tenomyoplasty - Step 6 (optional). If the two tendons cannot be brought together, an absorbable synthetic mesh can be used to bridge the gap. In time, the mesh will be replaced with fibrous tissue, maintaining medial hamstring continuity*

both midstance and terminal stance phases. In upright stance, both knees were flexed and the pelvis was tipped forward. Under general anesthesia, both knees exhibited a passive extension deficit of 40 degrees, with the hamstring tendons visible as tight cords under the skin.

Fractional (Merle D'Aubigné) lengthening of the biceps femoris (*Fig. 10*) was performed alongside the Burnei tenomyoplasty, achieving full knee extension. Postoperatively, the knee was immobilized in a plaster cast for 30 days, followed by physical therapy.

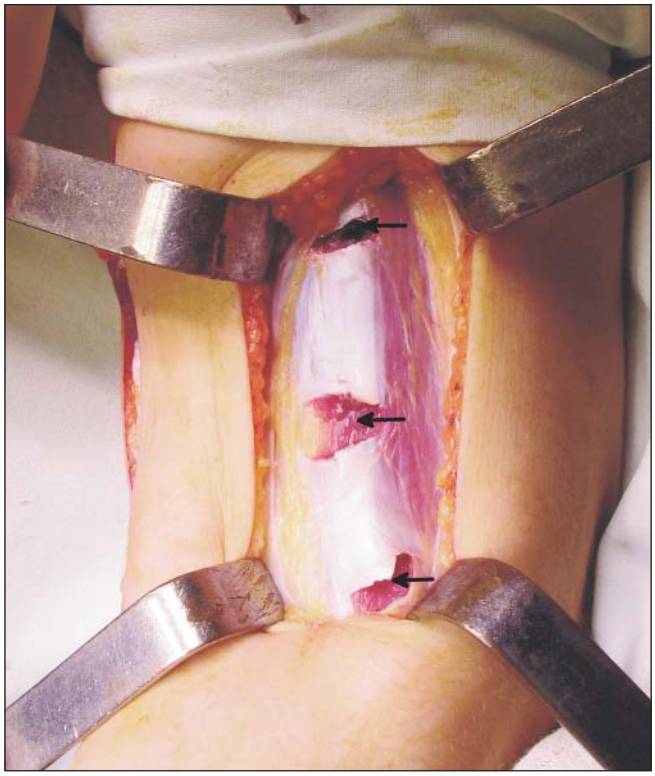

Figure 10. *Fractional lengthening of the biceps femoris*

Case 2. An exceptional case of genu flexum in arthrogryposis

Out of all our operated patients, one stood out dramatically. The girl, born in 2003, was diagnosed after birth with multiple congenital arthrogryposis. She had been unable to walk until the age of three, when she underwent bilateral Achilles tendon lengthening. Afterwards, she was able to ambulate only with an extreme crouch gait, with knees and hips fully flexed (*Fig. 11*).

Clinically, she had 90 degrees of extension deficit in both knees and her pelvis was tipped forward.

At the age of 9, she underwent combined Herbert capsuloplasty and Burnei tenomyoplasty for both knees, along with bilateral surgical release for coxa flexa.

Immediately after surgery, the left knee had 20 degrees of residual flexion deformity; both hips and the right knee could be placed in extension. However, when the right lower limb was tentatively placed in full extension, blood flow to the limb would cease, presumably because of the stretching of the bifurcation of the aorta and right iliac artery against the posterior bony reliefs. Because of this, the extension of the right lower limb was done in two stages, at 7 and 14 days, using successive plaster casts.

In children that exhibit such long-standing deformities, acute or chronic limb ischemia may also be caused by retractile fibrous bands which divert the course of the main blood vessel.

Figure 11. *Exacerbated genu flexum after bilateral Achilles tendon lengthening in a child with arthrogryposis, now manifesting extreme crouch gait*

Discussion

The combination of Herbert capsuloplasty and distal tenomyoplasty of the medial hamstrings is indicated for cases of genu flexum with 30 - 60 degrees of extension deficit. An extension deficit ranging from 10 to 30 degrees is compatible with walking, especially if the underlying cause is cerebral palsy. Walking is difficult, with a typical gait pattern known as crouch gait.

Clinically, the degree of flexum deformity can be measured using the popliteal angle. With the patient supine, the hip is flexed 90 degrees and the knee is maximally extended. The popliteal angle is measured between the vertical axis and the axis of the tibia (*Fig. 12*).

On the operative table, with the patient anesthetized, Prof. Burnei and colleagues prefer to measure the limitation to knee extension with the patient in ventral decubitus and the pelvis in contact with the table surface. (*Fig. 13*) This method is more reliable for patients with associated ankle and hip contractures and for those with spastic quadriplegia.

Spastic contracture of the knee where extension is limited by 30 to 60 degrees does not allow the patient to walk. Should only Achilles tendon lengthening be performed, the flexion deformity of the knees only increases and the patient may not be able to ambulate except in an extreme crouch gait. The lengthening of the Achilles tendon worsens the imbalance between the muscle groups involved in walking by breaking the chain of triple extension (8). In order to avoid the development or worsening of genu flexum, isolated Achilles tendon lengthening must be avoided in patients with cerebral palsy associated with coxa flexa and/or genu flexum (3).

The modern approach to spastic lower limb deformities (9), in use at our clinic, states that the hip, knee and ankle should undergo multi-level surgery in the same operative session, in order to maintain the balance between flexors and extensors, and to preserve the kinetic muscular chains that are so important to upright stance and gait. The procedures that may be performed in a multi-level surgery include soft tissue hip

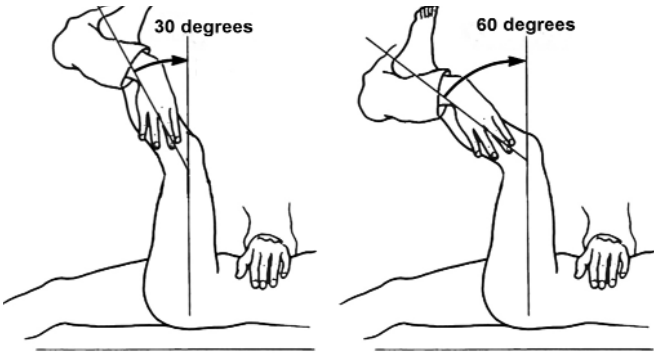

Figure 12. *The quantification of the loss of extension in genu flexum: in the supine patient, the thigh is raised vertically, while steadying the pelvis with the left hand, and the knee is extended as far as it allows it*

Figure 13. *Assessment of knee flexion deficit on the operating table*

and knee releases, proximal femoral and/or pelvic osteotomies for hip dysplasia or dislocation and Achilles tendon lengthening (preferably percutaneous). Complex foot deformities (equinovarus, equinovalgus, rocker-bottom foot, etc.) may be corrected during a multi-level surgery only if all prognostic factors for the outcome of the foot intervention are favorable; otherwise, the surgery should be done at a later time.

Flexion deformity greater than 60 degrees requires corrective surgery, aiming for increased patient comfort and ease of care, and even to restore ambulation. Residual genu flexum requires a supracondylar femoral osteotomy (10). Our clinic, under Prof. Burnei, has developed the "V - Y" distal femoral osteotomy, which is useful in cases of genu flexum that cannot be corrected by soft tissue release alone. The intervention comprises an extension and shortening osteotomy of the distal femur, in which a short intercalary fragment is removed from the distal one third of the femur and the bone ends are cut in the shape of a concave and convex dihedral angle, respectively (*Fig. 14*). The large contact surface between the fragments increases stability and promotes consolidation, and the shortening of the femur releases the tension of the hamstrings. The osteotomy is fixed, at the surgeon's discretion, using elastic rods, a locked intramedullary nail, or a plate and screws. Other authors describe an extension osteotomy and internal fixation using a special plate.

Posttraumatic genu flexum may occur after severe trauma resulting in comminuted fractures of the distal femur and/or proximal tibia, especially if the injuries had been inadequately treated. The combination of Herbert capsuloplasty and Burnei tenomyoplasty is suitable if the articular surfaces are congruent, the mechanical axes of the femur and tibia are properly aligned, the flexion deficit is 60 degrees or less and the deformity is caused by muscular contracture. The Burnei "V – Y" distal femoral osteotomy is indicated for malunited fractures with knee subluxation and axial deviation.

Genu flexum can be encountered after lengthening of the femur using an external fixator that does not span the knee, or because of articular protrusion of a Bailey-Dubow or Sheffield rod that has been implanted for osteogenesis

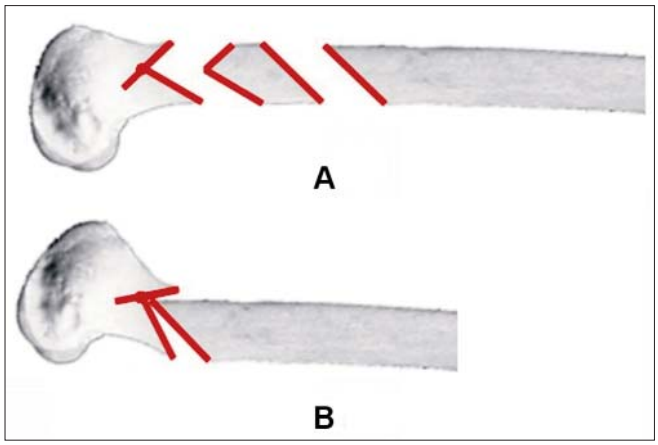

Figure 14. *The Burnei „V - Y" distal femoral shortening and extension osteotomy, one treatment option for cases where soft tissue release is not sufficient.*
A - osteotomies; B - final configuration

imperfecta. Although their use has been a net improvement in the treatment of osteogenesis imperfecta, a number of disadvantages determined that these rods be abandoned by most authors (11).

Our clinic also employs Herbert capsuloplasty and Burnei tenomyoplasty for patients with osteogenesis imperfecta and iatrogenic genu flexum. The procedure is indicated when osteodensitometry shows a Z score of less than -2.5 on two subsequent measurements three months apart.

Some of the possible complications include skin necrosis, vascular and nervous injuries, subluxation of the knee and recurrence (12). In the long term, cases of genu flexum associated with cerebral palsy that underwent tendon lengthening exhibited improved knee mobility in the first four years after surgery; from the fifth postoperative year, flexion deformity tended to recur, especially in the form of dynamic flexion during gait (13).

Surgical treatment of genu flexum, when included in a comprehensive multi-level single operation of a spastic lower limb, yields satisfactory results regarding knee function, in

the short and medium term. In the long term however, the rate of recurrence is significant (14). In the growing child, recurrence may be caused by the imbalance between available muscle strength and increasing body mass (15). Another suspected causal factor for this gradual deterioration is the abnormal development of the muscular system seen in spastic children (16).

Conclusions

The association between Herbert capsuloplasty and hamstring tenomyoplasty:

1. Corrects knee fixed flexion deformity;
2. Allows upright ambulation, with or without support;
3. Prevents the progression of the deformity beyond 60 degrees, which would require an osteotomy;
4. Prevents the chondral lesions which can develop when the knee is forced into extension, in children with a flexion deformity ranging between 30 and 60 degrees preoperatively and who are treated only with Herbert capsuloplasty;
5. Prevents knee subluxation and dislocation.

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