Chirurgia Narządów Ruchu i Ortopedia Polska – Polish Orthopaedics
ISSN 0009-479X, e-ISSN 2956-4719

Diagnosis and treatment of crouch gait in children with cerebral palsy. Report from the 4th Edition of the Transatlantic Orthopedic Surgery Webinar 2022

Diagnostyka i leczenie chodu kucznego u osób z mózgowym porażeniem dziecięcym. Raport z 4. edycji Transatlantic Ortopedic Surgery Webinar 2022

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REPORT

Chir Narzadow Ruchu Ortop Pol, 2023; 88(1): 30-40

DOI: 10.31139/chnriop.2023.88.1.5

Level of evidence: V

Received: 28.02.2023
Accepted: 17.03.2023
Published: 31.03.2023

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Cite this article:
Jóźwiak M, Woźniak Ł, Al-Shakarchi Z, Bernius P, Wade Shrader M, Rodby-Bousquet E: Diagnosis and treatment of crouch gait in children with cerebral palsy Report from the 4th edition of the Transatlantic Orthopedic Surgery Webinar 2022. Chir Narzadow Ruchu Ortop Pol, 2023; 88(1): 30-40.
DOI: 10.31139/chnriop.2023.88.1.5

Abstract

Introduction. The fourth edition of the Transatlantic Orthopedic Surgery Webinar 2022 took place on December 12th, 2022. The main theme of the webinar was the treatment of crouch gait in children with cerebral palsy (CP). Speakers from Australia, Canada, China, Germany, India, Poland, Spain, Sweden, Turkey, the United Kingdom, and the United States participated.
Results. The first general session presented the biomechanics of crouch gait, the function of the hip and knee muscles in children with CP, the principles of prevention and treatment of crouch gait in spastic diplegia, and the natural course and treatment outcomes of CP in adults. The surgical sessions comprehensively presented the surgical techniques for treating crouch gait: percutaneous myofasciotomy in the posterior knee joint, straightening osteotomy of the distal femur in hemiplegia, asymmetric and symmetric diplegia, techniques for shortening and plastically reconstructing the patellar ligament, anterior hemiepiphysiodesis of the distal femur, and transfer of the hamstring muscles to the rectus femoris muscle.
The second general session presented postoperative standing and walking rehabilitation protocols and evaluation of treatment outcomes (pain, fatigue, ambulatory activity, motor function, and quality of life).
Summary. The most important conclusions from the event were: do not lengthen the Achilles tendon in zone III in crouch gait; laboratory gait analysis is necessary before lengthening the hamstring muscles; hemiepiphysiodesis of the distal femur can be performed when the predicted growth period is less than two years; distal femur osteotomy should be considered during adolescence for knee flexion contracture of 10-40 degrees; treatment possibilities of tendon transfers and myofasciotomies should be remembered, especially in younger patients. The webinar attracted an audience of approximately 1,600 people from 672 centers located in 57 countries. Most participants came from Poland, the United Kingdom, the United States, Norway, Sweden, and India.

Key words: cerebral palsy, crouch gait, lever-arm deformities of lower limbs, gait laboratory.

Streszczenie

Wstęp. Czwarta edycja Transatlantic Orthopedic Surgery Webinar 2022 miała miejsce 12 grudnia 2022 roku. Tematem przewodnim webinarium było leczenie chodu kucznego u dzieci z mózgowym porażeniem dziecięcym (mpd). W wydarzeniu brali udział prelegenci z Australii, Chin, Hiszpanii, Indii, Kanady, Niemiec, Polski, Szwecji, Turcji, USA i Wielkiej Brytanii.
Wyniki. W pierwszej sesji ogólnej przedstawiono biomechanikę chodu kucznego, funkcję mięśni kulszowo-goleniowych u dzieci z mpd, założenia profilaktyki i zasady leczenia chodu kucznego w diplegii spastycznej oraz przebieg naturalny i wyniki leczenia patologii u osób dorosłych chorujących na mpd. W sesjach chirurgicznych przedstawiono kompleksowo techniki operacyjne leczenia chodu kucznego: przezskórną miofasciotomię w przedziale tylnym stawu kolanowego, osteotomię wyprostną końca dalszego kości udowej w hemiplegii, asymetrycznej i symetrycznej diplegii, techniki skrócenia i plikacji więzadła rzepki, hemiepifizjodezę przednią końca dalszego kości udowej oraz transfer mięśni kulszowo-goleniowych na mięsień prosty uda. W drugiej sesji ogólnej przedstawiono protokoły rehabilitacji pooperacyjnej zakładające pionizację i chodzenie, ocenę wyniku leczenia (ból, męczliwość, aktywność ruchowa związaną z ambulacją, funkcję ruchową, jakość życia).
Podsumowanie. Najważniejsze wnioski płynące z wydarzenia to: nie wydłużamy ścięgna Achillesa w strefie III w chodzie kucznym; przed wydłużeniem mięśni kulszowo-goleniowych niezbędna jest laboratoryjna ocena chodu; hemiepifizjodeza końca dalszego kości udowej może być wykonana przy przewidywanym okresie wzrastania krótszym niż 2 lata; osteotomia końca dalszego kości udowej powinna być rozważana w okresie dojrzewania dla przykurczu zgięciowego w stawie kolanowym 10-40 stopni; należy pamiętać o możliwości leczenia poprzez transfery ścięgien i miofasciotomie, zwłaszcza u młodszych pacjentów. Audytorium webinarium liczyło około 1600 osób z 672 ośrodków zlokalizowanych w 57 krajach. Największa liczba uczestników pochodziła z Polski, Wielkiej Brytanii, Stanów Zjednoczonych Ameryki, Norwegii, Szwecji i Indii.

Słowa kluczowe: mózgowe porażenie dziecięce, chód kuczny, dźwigniowozależne deformacje kończyn dolnych, laboratoryjna diagnostyka chodu.

Introduction

The Transatlantic Orthopedic Surgery webinar is an annual worldwide event dedicated to the pathophysiology, diagnosis, and treatment of selected orthopedic issues in developmental neuro-orthopedics, mainly cerebral palsy (CP). The event, originally broadcast live from operating rooms, was addressed to orthopedic surgeons, neurologists, and rehabilitation specialists dealing with functional impairments in CP. The fourth edition of the Transatlantic Orthopedic Surgery Webinar 2022 took place on December 12th, 2022, under the auspices of the Polish Academy of Childhood Disability (PANDA) and the European Academy of Childhood Disability (EACD). In addition, as a combined event, international organizations such as the American Academy of Cerebral Palsy and Developmental Disability (AACPDM), the European Pediatric Orthopaedic Society (EPOS), and the Pediatric Orthopedic Society of North America (POSNA) also participated in the event. According to the evolution of the event's concept, it is now addressed to a broader audience, including orthopedic surgeons, physicians of other specialties, and physiotherapists. The webinar includes a theoretical and surgical-workshop part with an extensive summary in the form of a clinical consensus discussion.

The main topic of the webinar was the treatment of crouch gait in children with cerebral palsy (CP). The event was led by Prof. Marek Jóźwiak and moderated by Dr. Łukasz Woźniak and Dr. Elisabet Rodby-Bousqet from Lund University in Sweden. Several surgeries were presented during the webinar, which was broadcast from ten operating rooms in Munich, Germany; Madrid, Spain; Istanbul, Turkey; Mumbai, India; Shenzhen, China; Melbourne, Australia; San Diego, Wilmington, and Saint Paul in the United States; and Poznań, Poland. The presented surgeries covered a wide range of procedures, including minimally invasive techniques used in treating crouch gait in CP.

Thanks to the webinar, participants had a unique opportunity to learn about procedures that correct the fixed flexion deformity of the knee joint, with a particular emphasis on establishing indications and contraindications for surgical treatment. A broad discussion was held on the justification for lengthening the hamstrings muscles, and attention was drawn to how to avoid errors in planning and implementing the treatment plan. Experts in neuro-orthopedics had the opportunity to exchange views, experiences, and technical details with participants from around the world, including countries with a low gross domestic product, such as Colombia, Malaysia, Sri Lanka, Ukraine, and Uzbekistan.

The organizing committee of the event included:

- Marek Jóźwiak from the Department of Pediatric Orthopedics and Traumatology at the Poznań University of Medical Sciences
- Peter Bernius from the Schöen Clinic in Munich, Germany
- Michael Wade Shrader from the Alfred d'Point Numerous Children Hospital in Wilmington, USA
- Elisabeth Rodby-Bousquet from Lund University, Sweden
- Łukasz Woźniak from the Department of Pediatric Orthopedics and Traumatology at the Poznań University of Medical Sciences
- Zaid Al-Shakarchi - medical student of the Poznań University of Medical Sciences

The Scientific Committee of the event included:

- Peter Bernius from the Schöen Clinic in Munich, Germany
- Hank Chambers from the Rady Children's Hospital in San Diego, USA
- Lin Feng from the Department of Pediatric Orthopedics at the Hong Kong University Shenzhen Hospital, China
- Martin Gough from Evelina London Children's Hospital in London, UK
- Kerr Graham from The Royal Children's Hospital in Melbourne, Australia
- Muharrem Inan from the Acibadem University Hospital Atakent in Istanbul, Turkey
- Ashok Johari from the Children's Orthopaedic Centre in Mumbai, India
- Marek Jóźwiak from the Department of Pediatric Orthopedics and Traumatology at the Poznań University of Medical Sciences, Poland – Chair of the Scientific Committee
- Robert M. Kay from the Orthopedics Children's Hospital in Los Angeles, USA
- Ignacio Martinez Caballero from the Hospital del Niño Jesús in Madrid, Spain
- Tom Novacheck from the Gillette Children's Hospital in Saint Paul, MN, USA
- Elisabet Rodby-Bousquet from Lund University, Sweden (EACD Education Committee)
- Michael Wade Shrader from the Nemours/Alfred I. duPont Hospital for Children in Wilmington, DE, USA

Results

GENERAL SESSION 1

Tom Novacheck – Crouch gait biomechanics

The plantar flexors of the ankle joint account for 50% of the stabilization of the limb during the loading phase, while the extensors of the hip and knee joint for the rest of the limb [1]. Crouch gait is characterized by the lack of extension of the lower limb at the knee joint in the limb transfer phase and excessive flexion of the joint in the stance phase. We define the crouch gait based on the position of

the knee joint, regardless of the simultaneous setting of the pelvis and the ankle joint. The moment of force, in simple terms, is defined as the product of the force and the arm of the force. During the crouch gait, we observe an excessive moment of forces straightening the knee joint in the entire stance phase, while in healthy patients, this moment in the middle stance phase is zero.

Jump gait is defined as a pattern in which there is no full extension of the knee in the final phase of the transfer. There is excessive flexion and extensor moment of the knee joint in the initial phase of the stance (loading response), with the correct extension and no extensor moment of the knee joint in the later phase support.

Delp proved in 1996 that lengthening the soleus muscle by 1 cm reduces its strength by 50% [2]. The gastrocnemius is a two-joint muscle whose shortening in the stance phase, can result in equine tarsus, knee flexion contracture, or both. It generates a propulsive force in the rebound phase and flexes the knee in the initial transfer phase. A large percentage of patients exhibiting a crouch gait had undergone a lengthening of the Achilles tendon in the past.

Incorrect torsion of the shin causes the internal or external angle of progression of the foot, thus shortening the arm of the force acting on the ankle joint. In flat-valgus deformity, the arm of the plantar-flexing force of the ankle joint decreases – the point of contact of the foot with the ground moves from the heads of the metatarsal bones to the area of the navicular bone, located more proximally to the pivot point, which is the upper ankle joint. Remember that changing the arm of force depends on the joint's position: increased dorsiflexion in the ankle joint shortens the lever of the Achilles tendon on the ankle joint, thus reducing the moment of propulsive force. In crouch gait, we often observe a coincidence of weakness of the soleus muscle after its earlier elongation, valgus of the tarsus, shin torsion disorders, and excessive dorsiflexion in the ankle joint.

In the case of an anterior pelvic tilt, we observe hamstring elongation, whereas in a posterior pelvic tilt, the hamstring muscles are shortened. Surgical lengthening of the tendons of the hamstring muscles when the pelvis is in an anterior tilt causes its deepening and thus intensifies the crouch gait. Before deciding to lengthen the hamstrings, their length should always be assessed in a laboratory gait analysis image. At the same time, it is worth remembering that a fixed flexion contracture of the knee greater than 5 degrees prevents proper straight gait.

Martin Gough – Hamstring muscle function in children with cerebral palsy

The sarcomere, the basic unit of skeletal muscle, is composed of myosin and actin fibers. The peak force generated by a sarcomere occurs over a short length (2.1-2.2 microns), due to the most favorable alignment of myosin and actin fibers. The resting length of a muscle is close to its optimal length for generating force.

The strength of a muscle depends on the number of sarcomeres in the cross-section of its belly. Among the thigh and calf muscles, the semitendinosus muscle stretches the farthest, and has the smallest cross-section, generating the slightest force. On the other hand, the biceps femoris muscle is the shortest, has the largest cross-section, and generates the greatest force.

The thigh and calf muscles of those with cerebral palsy have a decreased number of mitochondria and reduced metabolic efficiency. In addition, there is an increased percentage of collagen in the muscle and increased resting length of sarcomeres. This results in reduced muscle strength and increased stiffness. Surgical lengthening of the tendons of the thigh and calf muscles can cause the sarcomeres to shorten and improve the optimal alignment of myosin and actin fibers, resulting in increased muscle strength. Initially, a slight improvement in gait deformity may cause the fibers to align more optimally within the sarcomeres and increase their power. However, as the deformity progresses, the sarcomeres become less effective. In addition, increasing body weight and worsening contracture of the knee and hip joints with age can also contribute to a decline in walking endurance.

Kerr Graham – Prevention of crouch gait in children with diplegia

There are four gait patterns in spastic diplegia: equinus gait, jump gait, apparent crouch, and crouch gait [3]. When defining the gait pattern, attention should be paid to the position of the knee and ankle joints. He quoted that the child with diplegia is spring-loaded, meaning that the child's extension position depends on muscles whose action can be compared to springs [4]. Therefore, it is necessary to avoid Achilles tendon lengthening as an initial procedure, as it leads to a deterioration of the gait pattern – the loss of one of the "springs."

The definition of severe crouch gait was presented, including knee flexion >30 degrees throughout the stance phase, combined with excessive dorsiflexion of the ankle joint and incomplete hip extension in various pelvis positions [5,6]. The data used to define different gait patterns comes from The Victorian Cerebral Palsy Register [7].

Factors that reduce the frequency of severe crouch gait include education of medical personnel (physiotherapists, rehabilitation doctors, and orthopedists), avoiding surgeries in children who walk without prior gait laboratory diagnostics, avoiding single-level procedures (prohibiting Achilles tendon lengthening in zone III), replacing single-level surgeries with simultaneous multi-level surgeries (SEMLS – single-event multi-level surgery), of which the Strayer operation is recommended for correcting equinus position [8]. The recommended orthosis for patients with diplegia is the AFO (ankle-foot orthosis) with a fixed ankle joint (the speaker doesn't use AFO orthoses with a mobile joint or SMO (supramalleolar orthosis) type orthoses just after the surgery).

Sharing his experience, he performs a laboratory gait assessment 3, 6, 9, and 12 months after surgery. He often recommends AFO orthoses with a mobile ankle joint that can be locked in place. After further gait laboratory evaluations and consultation with a physiotherapist, he decides to activate the ankle joint later in rehabilitation in many patients. Since introducing these guidelines in 1995, a reduction in the frequency of severe crouch gait has been observed in the Australian patient population with a functional level of GMFCS (Gross Motor Function Classification System) II-III [9], from 25% to <5% over 13 years [10]. He emphasized that it is crucial to correctly assess the length of the gastrocnemius and soleus muscles before surgery and to avoid lengthening the latter. Patients function better with a slightly short soleus muscle (even without orthoses) than after an excessive extension. Currently, most patients undergo Strayer lenghtening [8]. In a small percentage of cases, he performs the extension of the posterior group of the shin muscles by Baker [11]. The observed rate of severe crouch gait of <5% is likely due to the natural course of the disease. Hence the conclusion is that about 20% of cases could have been caused by iatrogenic complications resulting from the lengthening of the Achilles tendon. For the next 15 years, it was possible to maintain the percentage share of severe crouch gait <5%. However, since the COVID-19 pandemic, an increase in the number of patients has been observed, probably resulting from more difficult access to surgical treatment due to epidemiological restrictions. The professor strongly recommends reading the expert consensus on the treatment of crouch gait [12].

Michael Wade Schrader – Treatment principles of flexed knee gait

Crouch gait increases the forces acting on the knee joint, leading to greater joint surface loading and an increased risk of early degenerative changes. Crouch gait tends to worsen with age. The non-operative treatment of crouch gait involves using rigid AFO braces and physiotherapy. The choice of surgical treatment depends on the child's functional GMFCS level [9], age, and associated pathologies. In cases of obvious progression of crouch gait, the most common surgical option for children aged 6-8 years with GMFCS levels I-III is to consider lengthening the medial hamstrings. Before adolescence, around 8-10 years old, anterior distal femoral epiphysiodesis (ADFE) is often considered. The speaker believes this method is worth considering in younger patients and those over the age of 10. During adolescence (from 11 years old), a distal femoral extension osteotomy (DFEO) is most often performed. The decision to lengthen the lateral hamstring muscle group should always be carefully considered, as it can increase anterior pelvic tilt. The pelvic tilt, selective muscle control, and strength of the hamstrings should always be assessed before any surgical intervention. Simultaneous correction of flat-valgus foot decreases knee joint flexion contracture by about 5 degrees.

Hank Chambers – Crouch gait in adults with cerebral palsy

Adults with cerebral palsy have twice the risk of stroke and eight times the risk of myelopathy, most commonly cervical myelopathy [13]. It should be considered if a patient's walking endurance worsens around the age of 30-40. In such cases, magnetic resonance imaging of the spinal cord is indicated. Approximately 33% of adult patients lose the ability to walk independently, 65% experience chronic fatigue, and 60% experience chronic pain [13]. In 2009, Hanna reported a decline in functional scores on the Gross Motor Function Measure 66 (GMFM-66) [9] between the ages of 7-8 and 21 in the GMFCS III-V group [14].

In teenagers and adults, lengthening the hamstring muscles does not change the pelvic tilt and lumbar lordosis and does not yield good results, even when the pelvis is tilted backward. Botulinum toxin does not work in adults due to fixed contractures. With age, there is an increase in pelvic anteversion, flexion contracture of the knee joint, functional elongation of the hamstring muscle group, worsening of foot and toe valgus, and a fixed equinus position of the ankle joint. Increased femoral anteversion, external torsion of the tibia, and foot valgus also worsen the crouch gait.

In adults with high patellar placement, fractures of the inferior pole of the patella can occur. These fractures are difficult to heal and often require resection of the distal patella and re-fixation of the patellar ligament. In 2012, Steele demonstrated that increased knee flexion during the loading phase leads to increased forces acting on the hip, knee and patellofemoral joints [15]. The endoprosthetic replacement may be performed for massive degenerative changes in the patellofemoral joint.

Regarding orthotics for treating crouch gait, the presenter points to little difference between ankle-foot orthoses (AFO) and ground reaction ankle-foot orthoses (GRAFO).

Correcting crouch gait in adults is very difficult due to delayed bone healing, degenerative disease, loss of upper and lower limb muscle strength, and rapid fatigue. Most patients with moderate to severe crouch gait (>20 degrees of knee flexion during the loading phase) will require a wheelchair in the future. In the case of flexion contractures with angle values around 60 degrees, surgical treatment is challenging and carries a high risk of complications. Sometimes, it is worth preceding the operation with a series of corrective plaster casts.

SURGERY SESSION 1

Peter Bernius – Percutaneous miofasciotomies in posterior knee complex

In patients with cerebral palsy, there is a phenomenon of muscle tissue atrophy, which leads to a loss of elasticity. The myofasciotomy procedure causes muscle elongation. It is performed by incising the muscle tissue (not tendinous) in the muscle segment distant from the proximal or distal attachment. The choice of muscles subjected to myofasciotomy and the extent and depth of the incision depends on the patient's clinical condition. In the case of elongation of the posterior group of leg muscles, the author uses temporary immobilization in synthetic dressings, followed by ankle-stabilizing orthoses. In the case of hamstrings, a knee-stabilizing orthosis in extension is recommended. A soft elastic bandage is applied immediately after the surgery for 24 hours to prevent hematomas. The patient is mobilized in an upright position on the first day after the surgery and begins walking on the first or second day after the surgery. Daily stretching exercises and lymphatic drainage are recommended. However, the speaker emphasizes that he is not aggressive in rehabilitation and gives soft tissues time to adapt to tension and elasticity.

Myofasciotomies are effective in correcting knee flexion contracture. The procedure is characterized by less invasiveness than open surgeries, less blood loss and pain in the postoperative period, and no need for immobilization in a cast (except for the posterior group of leg muscles). The procedure can be combined with other techniques, such as derotation osteotomy of the femur. If reconstructive surgeries are necessary later in life, they are not performed in scarred tissues. The speaker also uses ethanol blocks in patients with dystonia. The technique differs from Nuzzo's operation in the location of the muscle-tendon lengthening – Dr. Nuzzo operates within the tendinous tissue rather than the muscular tissue.

Wade Schrader – Unilateral distal femur extension osteotomy (DFEO) in hemiplegia and asymmetric diplegia

The speaker presented the DFEO surgical technique for correcting flexion contracture of the knee joint in patients with spastic hemiplegia or asymmetric diplegia requiring unilateral correction. They perform a typical lateral approach to the far end of the distal part of the shaft and epiphysis. The periosteum is separated, and the bone is secured subperiosteally. The author uses a set of instruments that include Kirschner wires and Kirschner wires with an olive that are temporarily fixed to the bone, allowing for precise osteotomy. They remove a trapezoidal-shaped bone fragment with a shorter base facing backward. In cases where the angular value of the contracture is up to 30 degrees, the length of the shorter base of the trapezoid is usually 1-2 cm, while for deformities ranging from 30-50 degrees, it is 2-3 cm. Initially, they stabilize the plate to the distal fragment with locking screws inserted in places the Kirschner wires are located and then insert screws into the proximal fragment. A cortical screw is inserted first into the proximal fragment to compress the elements, followed by locking screws. It is essential to maintain proper femoral torsion or correct any planned torsional disorders (torsion markers). The speaker then performs a patellar ligament shortening. They make an incision above the patellar ligament in the midline. After dissecting both sides of the ligament, they grasp it transversely with forceps, wrap it around the instrument once, and then suture it multiple times with non-absorbable sutures to create the ligament plication. The speaker prefers this method to the distal transfer of the tibial tuberosity in skeletally mature patients.

Marek Jóźwiak – Femur distal rotation osteotomy with Distal Femur Osteotomy System and patellar tendon advancement

The presenter described the technique of performing a distal femoral extension osteotomy (DFEO) on a 16-year-old patient with spastic diplegia and a functional level of GMFCS III. Emphasis was placed on the need to perform a clinical assessment of the patient's flexion contracture and torsional deformities under anesthesia on the operating table to ensure accurate evaluation.

The procedure is performed similarly to the technique presented by Michael W. Shrader. The Kirschner wires without the olive from the set stabilize the plate. One wire is introduced percutaneously in the proximal part of the diaphysis, and the other is inserted into the metaphysis. A trapezoidal bone segment is then excised with a shorter base located on the posterior aspect of the femur. The decision to shorten the femur is based on the intraoperative assessment of the popliteal angle after anesthesia. Torsional deformities of the femur can be corrected in the distal part if they are less than 35-40 degrees. For more severe deformities, detorsion osteotomy of the proximal femur is required. The aim is to achieve an external rotation of the hip joint that is approximately twice that of the internal rotation when the hip is flexed to 90 degrees and for these values to be similar when the hip is extended.

The patellar ligament is additionally strengthened with FiberTape. The loop is inserted over the patella, through the quadriceps tendon, and a tunnel drilled in the tibial tuberosity. After fixation of the tape, knee flexion should be possible to a minimum of approximately 70 degrees. Tom Novacheck also uses FiberTape to stabilize the knee joint in extension and aims to achieve flexion of 70-90 degrees intraoperatively to confirm proper stabilization.

Ashok Johari – Femur distal extension osteotomy and patellar tendon advancement

Askoh Johari presented his surgical technique for performing DFEO. The approach to the bone was carried out similarly to previous presenters. He marked the detorsion of the femur by making a shallow cut in the distal part of the shaft and the epiphysis of the femur using a saw. He determined the degree of femoral shortening intraoperatively after performing the transverse osteotomy of the femur. He dislocated the proximal fragment to the side at a knee flexion of 90 degrees. He determined the degree of shortening by the amount of overlap between the distal and proximal fragments. He resected a trapezoidal bone fragment. During the stabilization of the fractures, he emphasized the need to avoid the posterior translation of the distal fragment relative to the proximal fragment to prevent bayonet deformity of the distal femoral end. The presenter stabilized the fragments using a 5-hole straight LCP plate and four locking screws. He considered this stabilization sufficient but recommended postoperative immobilization with a plaster cast. He shortened the patellar ligament by making a transverse drill hole in the patella and passing a non-absorbable suture through it (transversely to the long axis of the limb). He then folded the ligament from the medial side by stitching the suture multiple times along the medial edge of the ligament before stitching the ligament transversely in the distal part and returning the suture along the lateral border of the ligament. He tied the suture to its proximal portion, located at the entrance of the previously drilled tunnel in the patella. He added additional non-absorbable sutures in the central part of the ligament to achieve further folding. The presenter noted that potential causes of pain in the anterior compartment after this procedure include excessive patellar impingement or degenerative changes in the anterior compartment, although this complication is not commonly encountered. He warned against performing bone fragments translocation in the sagittal plane to avoid vascular and nerve bundle injury. He experienced one case of this complication in patients with multiple osteochondromatosis, so he recommended caution in patients with broad epiphyses.

Muharrem Inan – Patellar tendon advancement

Patellar ligament duplication is always performed together with distal femoral osteotomy when the knee joint's extension deficit is between 20 and 40 degrees. For flexion contractures ranging between 10 and 20 degrees, the decision to perform patellar ligament duplication is made after performing osteotomy and assessing the patella position. The presenter demonstrated three surgical techniques he uses:

1. The ligament is prepared similarly to the technique presented by previous presenters. The patellar ligament is split in the frontal plane, the anterior part of the ligament is severed distally at the tibial tuberosity attachment, and the posterior part of the ligament is sutured with non-absorbable stitches and stabilized. Then, the anterior part of the patellar ligament is sutured onto the posterior part.
2. A transverse skin incision of approximately 4 cm is made between the lower pole of the patella and the tibial tuberosity. The patellar ligament is plicated and sutured on a strong Kocher. The proximal part of the ligament is sutured to both patellar retinacula. The correct patellar position is confirmed by radiography, and stabilizing sutures are applied to the previously sutured ligament.
3. A percutaneous patellar ligament plication using FiberWire tape: a long needle with tape is initially pierced over the patella through the quadriceps tendon. The needle then goes subcutaneously along the medial border of the patella to the level of its lower pole. The next puncture is made subcutaneously along the patellar ligament to the distal part of the tibial tuberosity. The tibia is drilled from the side to the medial aspect using a drill guide to protect soft tissues. The tape is passed on a long needle from the medial to the lateral side through the tunnel previously created. The tape is then passed subcutaneously along the lateral border of the patellar ligament and then along the lateral edge of the patella. The two tape ends are tied to achieve the desired patellar position. After the procedure, intraoperative knee flexion of 90 degrees is possible.

After the operation, a knee stabilizing orthosis is used for the first week with a range of motion between 0 and 30 degrees, then between 0 and 60 degrees until the third week after the operation, and finally between 0 and 90 degrees until the sixth week. The presenter's preferred method of treatment is the percutaneous technique. In the long-term follow-up after the operation, no limitation of the knee joint flexion range is observed.

Ignacio Martinez Caballero – Femur distal extension osteotomy with the Femur Locking Plate System

The presenter pointed out how to avoid errors during DFEO. When performing osteotomy without commercial guides, the osteotomy line often directs toward the medial part of the femur distally, which may affect the limb axis in the frontal plane. To avoid this problem, the bone is preliminarily drilled under x-ray control at the osteotomy site. Another problem is the fixation of the Femur Locking Plate 90 degrees, as the implant's thickness favors fixation of the distal fragment in a varus position. The author suggests temporarily inserting a chisel between the plate and the femur while inserting screws in the proximal fragment. To avoid sagittal bowing, the distal fragment should be translated backward. To do this, the directional wires determining the screw placement in the distal fragment should be placed slightly forward (closer to the anterior cortical layer of the femur). The posterior bony prominence is removed

when the knee joint is set at 90 degrees of flexion to prevent damage to the neurovascular bundle.

The presenter performs the osteotomy from the typical lateral approach. The distal directional wires are placed about 2 centimeters above the growth plate. Before performing the osteotomy, the bone is drilled under RTG-TV control in the future osteotomy site. The distal fragment is stabilized with three blocked screws. Then, a cortical screw is screwed into the proximal fragment, compressing the elements, and a blocked screw with a chisel under the plate is placed. After initial stabilization, rotational movements of the hip joint and the fragment's position are assessed under x-ray control. Then, the remaining blocked screws are inserted into the proximal fragment. Patients begin weight-bearing one month after the surgery.

SURGERY SESSION 2

Tom Novacheck – Distal femoral hemiepiphysiodesis

Initially, for anterior distal femoral epiphysiodesis (ADFE), two 8-plate implants were placed on the growth plate from the front. However, this method was discontinued due to frequent anterior knee pain.

In the currently used ADFE method, the speaker employs two cannulated screws with a total thread diameter of 4.5 mm. The procedure is recommended to be performed using two fluoroscopic C-arm devices positioned at a 90-degree angle to each other. The patient is placed on their back, and radiolucent knee support is located under the affected limb, maintaining a knee flexion of approximately 45 degrees. The lateral C-arm is positioned first, slightly tilted downwards towards the patient's head, and the anterior-posterior arm is approached from the patient's foot side. The C-arm is slightly angled towards the patient's head.

The first incision, approximately 1 centimeter long, is made on the anterior-lateral surface of the thigh. A window in the fascia is created using scissors, and a Kirschner wire is inserted at 1/3 of the anterior portion at the level of the distal femoral epiphysis, starting about 2-3 centimeters above the growth plate. The wire is guided as vertically as possible upwards, as the knee joint is flexed at 45 degrees. The skin is protected with a moist gauze during the wire insertion. The position of the wire is then checked using real-time X-ray imaging in the lateral and anterior-posterior views.

Subsequently, the nearer cortex is drilled, and the length of the screw is measured. The screw length is determined to be 1-2 millimeters longer than the measured length to enable easier removal. The 4.5 mm fully threaded screw is then inserted over the wire. The same procedure is repeated for the second screw, which is more challenging to

insert vertically due to the greater mass of the medial muscles. The speaker has not encountered permanent growth plate blockage after the procedure. The implants are removed when a knee extension of 5-10 degrees is achieved. The speaker notes that the method more frequently allows such an outcome compared to DFEO. The procedure results in a functional lengthening of the hamstring tendons but has little effect on pelvic tilt.

Robert M. Kay – Distal femoral hemiepiphysiodesis

According to the speaker, ADFE can also be performed on patients with a growth perspective of fewer than two years. They anticipate a correction of 0.5-1 degree of flexion contracture per month, which translates to twice the correction of knee joint alignment in a weight-bearing position. It is essential to note the need for a wide sterile field to avoid interference with the instrumentation. The speaker uses a single C-arm, which is repositioned during the procedure. It is emphasized that wires should be introduced into the femur's lateral and medial (not anterior) cortical layers. 4.5mm fully threaded screws should pass through the articular cartilage in the anterior third. Implants that are 4-6mm longer than suggested by measurements are preferred to facilitate removal. After the procedure, a knee stabilizing brace is used 12 hours a day for 2-3 weeks, then at night. The patient can withstand full weight on the limb immediately after the procedure within the tolerated range. Radiological follow-up is performed every four months in the postoperative period. Among the complications of the surgery, the speaker mentions pain in 5% of patients, disturbances in the frontal plane, and difficulties in removing the implant. No permanent blocking of growth plates has been encountered, despite the speaker's infrequent application of the technique to those under the age of 10. The implants are removed when hypercorrection of the deformity is achieved (in patients with open growth plates). The speaker also observes the effect of the procedure on the functional lengthening of the hamstring tendons. Simultaneous lengthening of the hamstring muscles is not performed in cases of pelvic retroversion. It is noted that a significant percentage of patients had previously undergone the procedure, and repeat lengthening does not yield good results. In cases of substantial active knee extension deficit (approximately 40 degrees), the speaker performs simultaneous shortening/plication of the patellar ligament (not waiting for correction or implant removal before performing the shortening or plication).

Kerr Graham – Patellar tendon shortening with hamstring lengthening and guided knee growth

The speaker presented two cases of patients who underwent patellar ligament plication and simultaneous hamstrings lengthening and ADFE with a long follow-up period. In both patients, the procedures were part of SEMLS. In both cases, a lasting improvement in gait parameters was achieved in the gait laboratory, FMS (Functional Mobility

System) [16], FAQ (Guilette Functional Assessment Questionnaire) [17], and a transition from functional group GMFCS III to II. Indications for performing simultaneous lengthening of the hamstrings and ADFE are crouch gait with posterior pelvic tilt in growing patients. The speaker emphasized that clinical examination should always be given as much consideration as gait analysis. In some patients with pronounced crouch gait, we observe a relatively small deficit of knee extension – they are good candidates for performing hemiepiphysiodesis. The indication for the procedure is a minor fixed flexion contracture of the knee joint, often with a significant deficit of active knee extension in the growing population of patients. The author performs patellar ligament plication according to Selber's method (simple plication of the ligament on a strong Kocher and stabilization with non-absorbable sutures) [12]. He also switched from using the 8-plate technique to cannulated screw fixation in ADFE. He pointed out that the growing population has a lot of soft tissue plasticity. Therefore, there is often secondary shortening of the quadriceps muscle, so he does not always perform patellar ligament plication during ADFE.

Lin Feng – Hamstring muscles to rectus femoris muscle transfer

The presenter discussed a technique for transferring the hamstring muscles to the rectus femoris muscle to correct knee flexion contractures in a crouch gait. The indication for the procedure is increased anterior pelvic tilt with simultaneous shortening of the hamstring muscles. Initially, the patient is placed in a prone position. A skin incision is made in the medial third of the distal thigh. The tendons of the semitendinosus and gracilis muscles are then dissected, and an intramuscular lengthening of the semimembranosus muscle is performed. The distal portion of the semitendinosus tendon, gracilis, or both is detached. If both tendons are detached, they are sutured together. Temporary closure of the operative wound is performed. The patient is then repositioned on their back during the operation. A further incision is made in the distal third of the thigh above the rectus femoris muscle. The rectus femoris muscle is dissected and detached from the patella, and its longitudinal duplication is performed. The previously detached hamstring muscles are transferred medially through the intermuscular septum and sutured to the duplicated and detached tendon of the rectus femoris muscle. Finally, the tension of the tendons is checked and assessed by palpation during flexion and extension of the knee joint. After the surgery, a stabilizing knee brace is used, and range-of-motion exercises are initiated. The patient bears weight on the limb within the tolerated range.

GENERAL SESSION 2

Marek Jóźwiak – Post-surgery rehabilitation protocols – standing and walking programs

The rehabilitation after surgical treatment aims to achieve a new or regain a lost pattern of standing and walking in daily life. The scope of the procedure, time of immobilization in a cast, and the duration of the period in which the patient does not bear weight on the limb and is not standing influence the function after (SEMLS). The speaker emphasized that immobilization after surgery should be as short as possible and drew attention to the need to modify rehabilitation programs resulting solely from the center's tradition of providing treatment.

Factors influencing the development of new walking patterns are muscle strength, motor coordination, range of motion of individual joints, balance during standing and walking, the general fitness level of the patient, postoperative pain intensity, fatigue level, and patient motivation. There is no single universal rehabilitation protocol after SEMLS. IIts determination should be dictated by the type of operation, the method of patellar ligament shortening/plication used, the GMFCS level, the type of immobilization of the patient after the procedure, the patient's intellectual level, the function of the upper limbs, the child's level of motivation, and cooperation with parents. Unfortunately, there is no scale for assessing the family's motivation for cooperation in rehabilitation. Psychologists, occupational therapists, and teachers with competencies for working with children with special needs play an essential role.

The following stages of rehabilitation are distinguished:

I. Bone consolidation period (6-8 weeks after surgery) – daily rehabilitation for 1.5-2 hours per day, exercises with 6-12 repetitions, without load or with functional load, focusing on regaining or achieving the maximum possible range of motion of the lower limb joints, especially the knee and hip joints.
II. Limb weight-bearing period (from 8-10 weeks to 3-6 months after surgery) – rehabilitation 3-5 times a week lasting 1-1.5 hours a day, training to adapt the patient to weight-bearing (standing frames, standing and walking with the help of a physiotherapist, Zero-G, Zebris, balance training on platforms).
III. Orthotic-supported walking period (from 3-6 to 9-12 months after surgery) – rehabilitation 2-4 times a week lasting 1-1.5 hours a day, treadmill training, 3-10 minute walking, balance, and overall physical fitness improvement.
IV. Independent walking period without aids for patients at GMFCS functional levels I-II or with aids used before surgery for patients at GMFCS III-IV (from 9-12 to 24 months after surgery) – rehabilitation 1-3 times a week lasting 1-1.5 hours per day, the training aimed at optimizing walking, aerobic and anaerobic endurance training, and balance and walking pattern improvement exercises.

During rehabilitation, one should remember the six words beginning with the letter F: Fitness, Function, Friends, Family, Fun, and Future [18].

Elisabet Rodby-Bousquet commented on the presentation and pointed out that it is worth informing the family before the operation about the need for intensive rehabilitation after the procedure. The patient's improvement process should be individually determined. In Sweden, fewer SEMLS are performed, and the emphasis is placed on early rehabilitation.

Michael Wade Schrader – Outcome measures – pain, fatigue, gait-related physical activity, motor function, quality of life

The results of the treatment of 49 patients by performing DFEO with a shortening of the patellar ligament were presented by Stout (2008) [19]. The average age of the patients was 14 years, and the average observation period was one year. A greater extension of the knee joint was observed in the initial contact phase and less knee flexion in the mid-stance phase with a sustained delay of knee flexion during the swing phase. Furthermore, better results were obtained in the GGI (Gillete's Gait Index) [20], Koshino Index (patella alta/baja) [21], and quadriceps muscle strength. Complications occurred in 18%, with peroneal nerve palsy accounting for 6%.

Geisbusch published midterm results of DFEO treatment for crouch gait during a 38-month follow-up [22]. Patients with functional levels GMFCS I-III were operated on at an average age of 11.8 years. Improvement in knee extension was demonstrated in the mid-stance phase and a decrease in knee flexion contracture to 3 degrees, as well as improvement in the GDI (Gait Deviation Index) [23].

Hyer presented the results of DFEO treatment with patellar ligament shortening in 28 children at functional levels GMFCS II-IV with an average age of 14.9 years [24]. The average observation period was 3.1 years. A statistically significant difference was shown in the value of knee flexion contracture, the deficit of active knee extension, quadriceps muscle strength, and decreased knee flexion during the initial and mid-stance. Recurrence of the deformity occurred in 14.2% of patients. In the case of recurrence, treatment consisted of botulinum toxin injections and corrective plaster casts.

A group from Mumbai led by Aroojis published the treatment results of 26 patients during an average observation period of 22 months [25]. Patients were at functional levels of GMFCS II-IV, and the average age at the time of surgery was 14.4 years. Improvement was observed in knee flexion contracture, quadriceps muscle strength, the decreased deficit of active knee extension, and better results in the Kashino Index [21], GMFM-D (GMFM Dimension D-standing) [9], FMS 5, but no differences in FMS 50 and 500 [16].

The results of the treatment of 28 patients at functional levels GMFCS I-IV using DFEO with patellar ligament shortening were presented by a group led by Boyer during a long observation period with an average of 13 years [26]. The average age of the patients at the time of surgery was 14.4 years. Improvement was observed in knee flexion at ground contact and an increase in the minimum value of knee flexion in the stance phase, with no improvement in patients' quality of life, level of physical activity, and life satisfaction. No difference was observed in FMS 5, 50, 500 [16].

Conclusions: DFEO performed with a shortening of the patellar ligament significantly improves knee flexion contracture, extension, and kinetics, but long-term studies do not show improvement in the quality of life and physical activity of patients. There is a need for more studies with longer observation periods. The speaker emphasized that rehabilitation after surgery likely contributes to the final outcome as much as the surgery itself.

Tom Novacheck commented on the presentation of Micheal Wade Schrader, stating that in the observation of his center, the long-term results of the treatment of crouch gait with extensor femoral osteotomy in terms of the quality of life of patients are comparable to other methods and should be considered reasonable. It questions whether we understand the natural course of the disease itself and calls attention to the need to reassess patients in the next 10-15 years. We must realize how much influence the surgeon has on the family and patient and that socio-economic factors often determine the final outcome.

Łukasz Woźniak – Takeaways

- Do not perform Achilles tendon lengthening in zone III during hip flexion.
- Before performing lengthening of the gastrocnemius muscles, always assess their length in a gait laboratory.
- ADFE is a suitable method for correcting crouch gait and can also be performed in patients with an anticipated growth period of fewer than two years.
- If considering ADFE and patellar ligament shortening, both procedures should be performed simultaneously.
- DFEO is a good method for treating children during the maturation period when the flexion contracture of the knee joint is between 10 and 30-40 degrees.
- Remember the possibility of treatment through tendon transfers and myofasciotomy, especially in younger patients.

Summary

Elisabet Rodby-Bousquet and Marek Jóźwiak thanked all participants and presenters and invited them to participate in next year's event. They pointed out the need for further research, including on patients' quality of life. The webinar audience consisted of approximately 1600 people from 672 centers in 57 countries (see Fig. 1). The most significant number of participants came from Poland, the United Kingdom, the United States, Norway, Sweden, and India (see Table 1).

Fig. 1. Distribution of participants by country.

Table 1. List of countries where the webinar was watched.		
1	Albania	2
2	Saudi Arabia	13
3	Argentina	14
4	Armenia	7
5	Australia	8
6	Austria	1
7	Belgium	12
8	Belarus	1
9	Brazil	9
10	China	29
11	Croatia	8
12	Denmark	7
13	Egypt	10
14	Finland	11
15	France	16
16	Greece	4
17	Georgia	8
18	Guatemala	1
19	Spain	28
20	Netherlands	8
21	Hong Kong	2
22	India	34
23	Ireland	26
24	Iceland	8
25	Israel	9
26	Japan	9
27	Jordan	2
28	Canada	11
29	Qatar	1

Table 1. Continuation		
30	Columbia	1
31	South Korea	1
32	Lithuania	1
33	Luxembourg	7
34	Latvia	1
35	Malaysia	2
36	Mexico	10
37	Germany	9
38	Norway	36
39	New Zealand	1
40	Paraguay	1
41	Peru	1
42	Poland	75
43	Portugal	7
44	Russia	14
45	South Africa	3
46	Romania	20
47	Singapore	2
48	Slovenia	1
49	Sri Lanka	18
50	United States	36
51	Switzerland	2
52	Sweden	36
53	Turkey	25
54	Ukraine	5
55	Uzbekistan	7
56	Great Britain	34
57	Italy	17
		672

The lecturers showed incredible commitment, especially those from extreme time zones - in California, it was early Monday morning, while in Melbourne in Australia and eastern China - late Tuesday night. However, this did not prevent lecturers from these regions from participating in the event. Many participants indicate the need to gain experience and knowledge in surgical techniques with the use of a powerful medium, the Internet. This allowed the participation of many young doctors, orthopedists, and orthopedic residents. In some centers, e.g., Gillette Institute in the USA, the webinar was broadcast in the lecture hall and watched as part of the residency meeting.

We wish to inform you that preparations for next year's edition of the event are already underway. This time it will be devoted to the issues of the neurogenic foot. The goal is to reach even more audiences in developing countries in Africa, Asia, and South America.

We want to inform you that the recording of the event is now available online at:

https://www.termedia.pl/Konferencja-IV-TRANSATLANTIC-ORTHOPEDIC-SURGERY-WEBINAR-TREATMENT-Intro,1872,22484.html#invitation

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