Surgical treatment and motor development in patients suffering from cerebral palsy

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Summary

The decision to operate on a child suffering from cerebral palsy (CP) should not be based solely on the orthopedic assessment, but also on other factors. Motor development, which is controlled by the CNS, is a factor of primary importance. The child must be classified according to the subgroups of defined locomotor stages and the quotient of retardation (the ratio between the developmental and the calendar age) must be calculated. This helps us to assess motor development in CP patients. Another way to evaluate motor development is to examine the quality of movements and primitive reflexes. Assessment of motor development helps us to choose the optimum age for possible surgery, the type of surgery, the rehabilitation techniques used after surgery and to predict the post surgical motor consequences.

Key words: cerebral palsy, motor development, stages of locomotion, retardation quotient.

Introduction

Orthopedic examination and treatment is an important part of complex care for patients suffering from cerebral palsy. The indication or contraindication criteria for surgical treatment, however, should not be derived from the orthopedic assessment alone. An approach that does not respect the individual aspect of the patient, along with the lack of communication between the medical specialists involved in the care of CP patients are the main causes of post-surgical complications.

In addition to orthopedic assessment, it is very important when considering surgical intervention in CP patients to take into account the principles of motor development controlled by the CNS.

The clear principles of motor development help us to form the locomotor prognosis and to determine the ratio between the real stage of locomotion and the stage that could be attained by the child with suitable treatment. This ratio is important in choosing the ideal age for surgery, the optimal type of surgery to fit the goal of the treatment and the best rehabilitation approach after surgery. It also helps us to predict the motor results of surgery.

The stages of locomotion and the quotient of retardation (RQ)

The course of motor development ending up in bipedal locomotion depends on the maturation of the CNS. It consists of several subsequent stages. Motor development is usually divided into 4 stages according to Ingram. (1,2).

1. Holokinetic stage (1^{st} -6^{th} week)
2. Holokinetic stage followed by early purposeful motor patterns (7^{th} – 13^{th} week or the 3^{rd}-4^{th} month)
3. The stage of attaining the erect posture distinctive to man (4^{th} – 12^{th} month)
4. Bipedal locomotion (12^{th} – 14^{th} month) characteristic

We consider the stages according to Vojta to be more useful for exact assessment of pathological development, since these stages respect the way the CNS controls function. They consist of 10 locomotor stages, with a rating of 0-9for assessing the level of gross motor functions (posture) developed by the child, his ability to perform precise movements, and his mental development. Motor development from the neonatal stage up to the age of 4 years (i.e. human motor ontogenesis) can be assessed in this way. There are two scales according to Vojta; one considers physiological development and the other pathological (children affected by CP).

Locomotion stages according to Vojta (physiological scale):
Stage 0: the child is "apedal"; cannot move forward using arms or legs, cannot make any motor contact with environment (turn over or grasp an object)
Stage 1: the child is "apedal"; cannot move forward, but can turn towards the object to touch or grasp it. The developmental age: 3^{rd} – 4^{th} month
Stage 2: the child is "apedal"; if the arm is in pronation it can serve for support. This is the first imperfect stage of straightening up. It tries to get close to an object but cannot move forward using arms or legs. It can grasp objects with the hand. The developmental age: late 4^{th} and 5^{th} month (second half of the 5^{th} month and the 6^{th} month: corresponds to the late second stage and early third stage)
Stage 3: the child can creep,- considered true locomotion- and can spontaneously move around the room. The developmental age: 7^{th} – 8^{th} month
Stage 4: the child "jumps" on arms and legs. It cannot move the center of gravity in the frontal plane. The support area is on the wrists or the fists. "Jumping" is not a crossed (contralateral) pattern like crawling. It is only an ipsilateral pattern and not real locomotion. If the child is unable to learn real locomotion it soon gives up. The pattern of "jumping" however is more advanced than creeping. At this stage of development the child cannot make a segmental movement (movement in one segment only) without simultaneous movement in other segments, e.g. moving the talocrural joint alone). Developmental age: 9 months
Stage 5: crawling. This is a contralateral pattern, support is provided by the fully opened hands. Any child who reached this stage of locomotion will be able to attain vertical posture later in the development. In children with central paresis this locomotor pattern can be considered as fully developed if the child can move around the whole apartment through his (her) own motivation.
Stage 6: using the arms the child can reach an erect position and maintain it actively. From this position side walking develops, which is still quadrupedal locomotion in the frontal plane. This is followed by locomotion in the sagittal plane with the arms supported. It is important that locomotion results from the emotional need of the child. Developmental age: 12-13 months.
Stage 7: The child walks by himself and does not depend on any support even when walking on uneven ground.
Stage 8: If stable the child can stand on one leg for 3 seconds. Developmental age: 3 years
Stage 9: The child can stand on one leg for a longer time than 3 seconds. This position is possible on both (either right or left) legs. Developmental age: 4 years.

In children suffering from cerebral palsy it is useful to determine the **quotient of retardation (RQ)**, which informs us about the level of verticalization and locomotion. To determine RQ we compare the developmental motor age (gross motor function, the level of verticalization and the stages of locomotion, as described above) that has been reached by the child, and the calendar age of the child

RQ= the developmental age/ the calendar age

RQ helps us to determine the developmental prognosis.

Example: a child suffering from CP, with a calendar age of 20 months. Motor development corresponds to the second stage of locomotion. The child is apedal, showing first signs of straightening up, i.e. if the arm is in pronation it can serve for support. It tries to get closer to the object but cannot move forward using the arms or the legs. When grasping, the hand is in ulnar flexion. This developmental stage corresponds to the end of the 4^{th} and early 5^{th} months of physiological development. The RQ can be calculated as the ratio between the developmental and calendar age:

RQ= 5 months / 20 months = ¼

The RQ tells us that, if the child is provided with good rehabilitation, during the next 12 months will make 3 months of developmental progress, i.e. the child will move around the room spontaneously by creeping. As a final prognosis we can predict that this child will reach vertical posture and use bipedal locomotion.
Clinically it is useful to re-calculate RQ after some time (at least 6 months). This helps us to assess the speed of motor development of the particular child more precisely. When calculating RQ it also is important to bear in mind whether the child receives rehabilitation. It helps us to assess the quality of rehabilitation. Therefore it is important to calculate the RQ before we start rehabilitation and after 6 (or even more) months of treatment. It is typical that the RQ decreases if (e.g. RQ = ¼ at first examination and RQ= 1/5 after 6 months) rehabilitation is insufficient.

Primitive reflexes and movement differentiation

In addition to motor development and RQ assessment it is important to examine isolated movements at both upper and lower extremities along with primitive reflexes. This also helps us to predict locomotor prognosis (whether the child can ever attain erect posture and develop bipedal locomotion), to define the real stage of locomotion and the best possible stage (capacity) of the child.

The most important **primitive reflexes are:**

Suprapubic reflex: We exert a slight (not nociceptive!) pressure on the upper edge of the symphysis. The response is: extension and inward rotation of the hip joints, knee extension, and plantar flexion of the feet with fanning out of the toes. The same response is observed on both legs. In older children observing the response of the feet is especially important.

Crossed extension reflex: With the baby supine we exert a slight pressure on the leg, which is flexed at the hip and the knee. We press on the flexed knee; the direction of the pressure is towards the hip joint. The reflex response can be observed on the contralateral leg: extension and inward rotation of the hip joint, knee extension, plantar flexion of the foot, extension of the metacarpophalangeal joints and flexion of the interphalangeal joints. Again, the feet response is especially important.

Support reaction: Stimulation of the soles of the feet is followed by extension (support) of the legs.

Primitive reflexes are processed at the spinal level of the CNS. The moment the balance function comes into play, i.e. muscular coactivation, the primitive reflexes become inhibited and cannot be evoked any more, even in children suffering from CP.

When examining **isolated movements** we assess the patient's ability to move one segment independently on the others (without synkinesis of the other segments). Fig. 1 shows the examination of the active movement of the foot. It is advisable to examine this movement with the knee flexed and the lower leg fixed. If the patient with CP has negative primitive reflexes and can actively make a differentiated movement in one segment we can expect him to reach vertical posture.

If the child with CP does not make any more progress in locomotion (there is no tendency to reach and attain vertical posture), his (her) primitive reflexes are negative or very slightly positive and he can do an isolated movements, it is necessary to find out why the motor development has stopped because such a child has not made use of all his (her) motor capacity. If muscular and tendon contractures are operated correctly, great locomotor effects can be expected after the surgery.

Example: A child with CP, 4th stage of locomotion. The suprapubic and crossed extension reflexes are negative or only slightly positive (not as strong as during the neonatal stage), no support reaction of the legs, good ability of isolated movements on the legs. It is not unusual that shortly after surgical treatment of contractures that the child reaches an erect posture and sometimes even starts bipedal locomotion. Before the operation there was discrepancy between the attained stage of locomotion and the best possible stage. This aspect is important for rehabilitation treatment after the surgery. In such children it is necessary to concentrate on training erect posture.

There is a problem with the following paragraph I think the sentences have been juxtaposed so it needs to be restructured so that it can be corrected grammatically
On the other hand if there is a child of the same developmental stage, but the primitive reflexes are strongly positive and there is very little or no ability of isolated movements in the lower extremities, we cannot expect a good post-surgical effect. Children who get good rehabilitation treatment from the neonatal stage onward reach the highest possible stage of locomotor development, which is not very stable, as they have made use of their maximum motor capacity that is limited by the disturbance. Adaptation after the surgery is therefore slower and limited. Therefore post-operative effect is limited in such children and any attempt of the therapist to teach them how to attain erect posture without some spontaneous ability in the child is counter-productive because only spinal activity is stimulated, resulting in increased spasticity.

Conclusions

1. Classification of children suffering from CP into 10 locomotory stages, according to the level of motor functions attained is important for documentation. It allows us to assess objectively the course of motor development.
2. The quotient of retardation (RQ) allows us to predict locomotor prognosis of the patient. It helps us to answer parent's questions as to whether the child can ever achieve the ability to walk and what final effect they can expect from rehabilitation. It is also important for choosing the proper type of surgery, according to its purpose; e.g. only a palliative operation or with the goal to improve locomotion, allow bipedal locomotion etc...

3. RQ, assessment of primitive postural reflexes (the responses typically change during development) and assessment of movement differentiation allow us to assess the process of straightening up (uprighting) and the development of locomotion. If the development slows down or no progress can be observed, the RQ changes, i.e. the ratio between the motor and calendar age increases, and it is necessary to find the reason for that. The most common reasons are insufficient rehabilitation, more frequent epileptic seizures etc. Another reason for motor development retardation, however, can be contractures resulting in morphological deformities (especially concerning the hip joint). At this stage orthopedic surgical treatment is necessary. Therefore, if the rehabilitation is of a good quality and intensity and the RQ increases, the motor development slows down and the child has been developing contractures, it is then necessary to refer him (her) for surgery. From the functional point of view this defines the optimal time for surgical treatment. The calendar age, by itself, is not decisive for timing the operation.
4. Follow up of the motor development in children suffering from CP allows us to better predict locomotor results of surgery. Before indicating surgery, it is essential to compare the level of the locomotor development that has been attained by the child, and the optimum possible stage that follows from the ratio between the developmental and calendar age. E.g. if this ratio was 1:4 at the age of 20 months and it is 1:10 at the age of 4 years; in such a child there is great discrepancy between the real stage of locomotion and the best possible stage. Assessing primitive reflexes and movement differentiation regularly during a longer period of time helps us to predict if the child could do better if there was proper rehabilitation. In such children very good progress in locomotion can be observed quite often after the surgery. On the other hand for children who have already reached the maximum possible level of locomotion, surgery will not prove to be so effective.

Fig. 1: Examination of the isolated movement. Patient is prone; we fix the lower leg and ask the patient to move the foot.