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Current principles of complex rehabilitation of children with stroke consequences

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The article is dedicated to an urgent issue of modern pediatrics and neurology – complex treatment of stroke consequences in children. The article details etiological aspects, pathophysiological mechanisms and clinical peculiarities of stroke consequences in children, the primary among which are asthenic syndrome (73-86% of the patients), movement disorders (33-58%), cognitive disorders (60%), paroxysmal conditions (30%), sensory disorders (14%), emotional-volitional and behavioral disorders (17-38%), vegetative dysfunction syndrome (60-74%), pain syndrome (53-74%) and syncopal conditions (12%). The article details the main spheres of complex rehabilitation of children with stroke consequences, including use of innovative medical rehabilitation technologies – kinesitherapy, dynamic proprioceptive correction, mechanotherapy using robotic systems, physiotherapy and drug correction. The article demonstrates that diagnosis and treatment of stroke consequences in children is a difficult problem, which requires a differential complex approach in order to improve effectiveness of both drug therapy and rehabilitation and quality of life of the patients.
Keywords: *children, stroke, rehabilitation, mechanotherapy, cerebral palsy, Gerstmann syndrome, dynamic proprioceptive correction.*

INTRODUCTION

Stroke is an acute disorder of cerebral circulation characterized by an abrupt manifestation of focal neurological symptoms within several minutes or hours (which is a rarer case). The symptoms include locomotor, speech, sensory, coordination, eyesight symptoms etc., and/or cerebral changes (consciousness, headache, emesis, etc.). Those persist for more than 24 hours or result in the patient's death in a shorter period of time due to a cerebrovascular cause [1-3]. Stroke prevalence in the pediatric population is two to three cases per 100 thousand children per year; 40% of the stroke-affected patients are infants [4-7].
The most important etiological factors of cerebral circulation disorder in children are congenital and acquired heart disease, blood system and coagulopathy pathologies, structural abnormalities of cerebral blood vessels, vasculitis and vasculopathies [4, 8-14]. There may be other risk factors of stroke development in children such as arterial hypertension, diabetes, hypovolemia and arterial hypotension, hypernatremia, MELAS syndrome (Mitochondrial encephalomyopathy, lactic acidosis, and stroke-like episodes), vasospastic conditions, migraine, and brain tumors. In 10 to 20 % of cases, the etiology of stroke remains unclear despite thorough diagnosis [15].

Periodization

The course of stroke is divided into the following phases [1]:

- peracute phase lasts for the first 3 to 5 days and is characterized by augmenting neurological symptoms;
- acute phase lasts up to day 21 and is characterized by relative stabilization of neurological deficiency;
- remedial phase is characterized by stabilized status of a patient and gradual reduction in pathological symptoms; lasts up to two years;
- residual effect phase commences two years after the stroke onset.

Stroke Outcomes

The main factors that influence the outcomes and sequelae of stroke in children is the nature of injury, its localization, site and area, the maturity of cerebral structures at the moment of emergence of the disturbing factor, innate recovery capacities of the brain, the child's sex and the treatment undergone [2, 16-20].

Outcomes of stroke in children vary significantly depending on the stroke type and the patient cohort under analysis [2]. Foreign studies show that *in case of ischemic stroke*, mortality amounts to 12%, whilst a full recovery of neurological functions is observed in 27% of cases; refractory neurological symptoms persist in 61% of cases, whereas frequency of episode recurrence is 21.6%. *In case of hemorrhagic stroke*, mortality amounts to 29%; full recovery is observed in 38% of cases, refractory neurological deficiency and/or symptomatic epilepsy – in 34% of cases; the frequency of recurrent hemorrhagic stroke episodes is 10% [5, 15]. According to Russian researchers, complete post-stroke recovery is observed in only 20 to 25% of the patients. In 70% of the cases, refractory neurological symptoms are observed; thereby, the most frequent outcomes are locomotor disorders (in 1/3 of the patients), cognitive disorders (60%), and difficulties with school education (15% to 20%), which cause disability in more than a half (51%) of pediatric patients [2, 9].

Stroke Sequelae

The most frequent remote sequelae of stroke in children are as follows [2, 9, 16, 21-26]:

1) locomotor disorders (33% to 58%): the most frequent among them is contralateral spastic hemiparesis, although dystonia, ataxia, and hyperkineses may also occur;
2) cognitive disorders (60%): stroke affects perception, memory, thinking, speech, reading, counting, and writing skills, as well as body image;
3) paroxysmal disorders, including epilepsy (7% to 30%);
4) sensory disorders (14%): the most frequent are prolapse or narrowing of visual fields as well as color perception disorders;
5) emotional-volitional and behavioral disorders (17% to 38%): emotional lability, aggressiveness, dysphoria, apathy, and depression;
6) vegetative dysfunction syndrome (60% to 74%): headaches, sleep disorders, dizziness, etc.;
7) pain syndrome (53% to 74%): cervicalgiae, central post-stroke pain, pain syndrome due to post-stroke arthropathies and spasticity;
8) asthenia (73% to 86%);
9) syncopal conditions (12%).

Neurophysiological peculiarities of development of stroke sequelae in children are related to the following factors [19, 27-30].

1. Early brain injury affects not only functions of the damaged structure (focal effect), but also underdeveloped functions (secondary underdevelopment effect).
2. Localization of cerebral functions in children is less distinct than in adults, and the nature of connection between structures and functions is unstable: earlier injury leads to more diffused disorders that depend less on the intrahemispheric localization of damage.

3. Children and adolescents recover better than adults.
4. Recovery trends are more apparent in case of early and localized injury.
5. One of the primary recovery mechanisms is the ability of an immature brain to reallocate functions within a hemisphere or between hemispheres.

Most children experience left hemisphere stroke 3 to 4 times more frequently than right hemisphere stroke; localization in the middle cerebral artery circulation is twice as frequent as in other arteries [27-30]. The left hemisphere is damaged more severely and more frequently than its right counterpart due to its slow and late maturation, anatomic peculiarities, and younger (in terms of phylogenesis) functions. The said peculiarities include different blood filling of the left and the right carotid artery; the left vertex fetal presentation being more frequent; and domination of blood circulation in the right hemisphere in neonates and under-3 children, especially in the dorsal association areas, which ultimately results in significant dominance of dextral hemipareses over sinistral ones.

In terms of development of residual locomotor disorders, the most unfavorable case is injury of the internal capsule, which leads to a complete limb paralysis, whilst earlier damage of greater cortex area may be well-compensated [23, 29]. Locomotor disorders due to early monohemispheric injury of the motor cortex are compensated by the frontal and the parietal area of the same hemisphere; disorders due to later injury are compensated by the motor areas of the contralateral hemisphere [26, 29, 31, 32].

Different researchers believe that in case of early cerebral injury, the potential for speech recovery persists for up to 1-12 years and depends on the sex: among girls, compensatory capabilities are more apparent in infants, whilst in boys, they are apparent until adolescence. If the injury is not significant in scale or occurs in an over-8 child, speech remains localized in the left hemisphere and is compensated by adjacent areas [33-35]. This is why when an early unilateral injury is compensated, no significant speech disorders are observed regardless of the affected side or etiology. Unlike adults, children rarely suffer aphasia [33-35]. Insignificant deficiency of speech is only noted when the left hemisphere is affected, and includes later development of phrase speech and insufficient comprehension of complex speech structures [34, 35]. Later injury of the left hemisphere in adolescents may result in a significant aphasia-like speech deficiency, as it does in adults [34].

Children whose left hemisphere has been affected display cognitive function disorders: optical-spatial agraphia (mirror drawing and writing), finger agnosia, reading and counting disorders, disorders of constructing due to simplification of detail-less construction (yet drawing skills may be preserved). The Wechsler Scale reveals low intelligence development values (verbal functions are affected heavier than non-verbal functions). If speech areas of the left hemisphere are affected, the test also reveals an atypical speech disorder manifesting itself as transient inapparent speech disorders (dyslalia, low speech activity, poorness of phrase speech). Degradation of verbal (hearing-and-speech) memory, inadequate interpretation of logical and grammatical constructions, yet the ability to abstract and generalize remains intact [19, 20, 22, 25, 28, 30, 34, 35].

Children whose right hemisphere has been affected display insufficient non-verbal intelligence, inadequate spatial orientation, constructing ability, and body image; underdeveloped visual-spatial analysis and synthesis; reduced non-verbal perception and non-verbal (visual) memory; disordered arithmetic skills (children are unable to recognize images of numbers); inability to perceive gestures, facial expressions and the emotional speech component, as well as to recognize faces. Speech disorders are rare and easily reversible; they include minor dyslalia, minor speech development delay. The Wechsler Scale shows reduced non-verbal intelligence value and emotional-volitional disorders (affective disorders, euphoria, infantility, anosognosia of the deficiency characterized by ignoring the affected limb and disengaging it from regular use) [19, 25, 26, 28, 31, 32].

When comparing sinistral and dextral hemiparesis in terms of motor and cognitive functions, researchers have revealed no difference in the speed of motor and intellectual development, yet

injury of the left hemisphere is distinguished by a higher frequency of speech disorders [27, 28, 30, 33, 34]. It has been shown that the localization of early cerebral injury does not impact the actualization of higher psychic functions: intelligence reduction is identified in cases of both sinistral and dextral hemiparesis and correlates not with the lateralization, but the extent to which the brain has been affected, the intensity of paresis as well as the presence of epileptic activity signs in the electroencephalogram (EEG). Presence of epileptic seizures has the strongest negative impact on IQ and movements [19, 35, 36].

PERINATAL CEREBRAL STROKE

In recent years, sequelae of perinatal stroke have become the area of focus for many researchers [2, 4, 10, 14, 16-18, 37]. Perinatal cerebral stroke is a cerebral circulation disorder that occurs within the time period from gestation week 22 to postnatal day 28.

Perinatal ischemic stroke is identified in one neonate per 4 to 5 thousand, whilst perinatal hemorrhagic stroke is identified in one live-born child per 16 to 17 thousand [4, 16, 17]. The prevalence of perinatal arterial stroke is 8 to 25 per 100 thousand in the world. In Russia, it is 13 per 100 thousand; in Moscow, it is 7.5 per 100 thousand [2, 5-7, 9]. Focal cerebral injury results from arterial neonatal stroke in 70% of all cases, whilst the remainder is constituted by venous neonatal stroke. The frequency of arterial ischemic stroke is one per 4 thousand live-born children [4. 6].

It has been shown that the presence of genetic disorders and susceptibility of neonates combined with unfavorable circumstances of labor and post-natal conditions may significantly increase risks of stroke [2, 4, 10, 12, 14]. The risk of neonatal arterial ischemic stroke is increased significantly by certain factors making a child susceptible to thrombophilia, as well as by the mother having a mutated *G1691A* gene of Leiden factor V, IIG20210A factor, or acquired antiphospholipid antibodies, when maternal antibodies to cardiolipin may cause thrombosis of fetoplacental vessels, and IgC antibodies may penetrate through the placenta and cause thrombosis in the embryo [4, 10, 12, 14]. Risk factors of stroke in embryos and neonates also include long labor, perinatal asphyxia, preeclampsia, emergency caesarean section, chorioamnionitis, neonatal post-thrombotic disorders, neonatal sepsis, meningitis and other CNS infections [12-14]. However, the cause of perinatal stroke remains unidentified in most cases [23].

The most frequent signs of perinatal ischemic stroke are impairments of consciousness, paresis and epileptic seizures [8, 9, 14, 15]. Approximately half of all cases are characterized by paroxysms within the first week of life. Meanwhile, later actualization of epilepsy episodes in children, both at infancy and later, has also been observed [9, 14-16].

According to K. Nelson, a third of perinatal stroke episodes is diagnosed at a later time [37]. Such late manifestation may present itself in the form of symptomatic epilepsies (usually of focal nature) [14]. Perinatal medical history of such children is often burdened. Early neurosonography does not yield data supporting the presence of perinatal stroke due to peculiarities of ultrasonography and presence of unreachable cerebral areas. The presence of cerebral injury site formed due to a survived perinatal stroke often results in pharmacoresistant epilepsies requiring a thorough choice of therapy [14].

The primary outcomes of perinatal stroke

The primary outcomes of perinatal stroke are

- full compensation (in a third of children);
- spastic hemiplegia (27-58%);
- mild locomotor disorders (32%);
- epilepsy (39%);
- speech development delay (25%);
- behavioral pathology (22%) [14-18].

According to some researchers, clinical manifestations do not distinctly depend on the neuroimaging-related intensity and localization of alterations [10, 15, 29]. It has been shown that 24% of children with ultrasonographic signs of a unilateral injury display adequate locomotor development, whilst 76% of those had hemiparesis, which was severe in 33% of these children [29]. It has been revealed that in case of early cerebral injury, the following served as tomographic predictors of hemiplegia: large affected area, involvement of the internal capsule, of the speech center or basal ganglia [29].

Researchers have not yet agreed on whether periventricular ischemic disease and intraventricular and subarachnoid hemorrhages as a morphological substrate of perinatal CNS injury in infants can be considered equivalent to ischemic and hemorrhagic stroke. Foreign researchers believe that stroke only accounts for 4.8% of all perinatal CNS injuries. Thereby, the most probable cases are embolic origin characterized by thrombus formation in the arterial duct or in umbilical vessels, or a hemodynamic nature of the pathology [29, 37]. Differential diagnosis becomes significantly more difficult due to the fact that in 60 to 67% of all cases, stroke etiology remains unknown [2, 9]. When trying to identify neuroimaging-related differential diagnostic signs of perinatal stroke, foreign researchers have noted that focal neonatal infarction in neonates features destruction of both white matter and grey matter caused by embolism, thrombosis or ischemic disease. Hemorrhagic focal cuneated injuries that affect the cortex, the sub-cortical and periventricular areas, often accompanied by secondary hemorrhagic infarction, may also occur [23, 29].

Scientists have not agreed on whether cerebral palsy (CP) may result from perinatal stroke. According to the results of a foreign study, perinatal arterial stroke is the main cause of hemiparetic CP forms [8]. At the same time, long-term studies by Russian researchers have shown that the primary cause of hemiparetic CP forms is perinatal traumatic CNS injury [38, 39], which cannot be considered stroke following the definition by the WHO, as stroke-related hemorrhage is non-traumatic.

In recent years, developmental Gerstmann syndrome (DGS) or angular gyros syndrome has become the area of focus for many scientists [22, 24, 26, 40]. There is a suggestion that this pathology is conditioned by injury of the lower angular gyros, or by sub-cortical injury. The angular gyros (parietal-temporal-occipital segments) in the right hemisphere performs the functions that form the base of visual and spatial perceptions and constructional praxis; in the left hemisphere, it enables counting, reading and writing [19, 26, 33, 34, 40]. It has been shown that blood is supplied to the angular gyros mostly by terminal arteries (at the circulation boundaries): during the perinatal period, hypoxia and asphyxia may result in an injury of parietal-temporal-occipital association segments akin to hemodynamic stroke, the injury whereof is caused by reduced blood pressure in the terminal arteries; thereby, the left hemisphere remains more vulnerable. Vasography of CP-affected patients with hemipareses indicates disorders of the middle cerebral arterial system [38].

REMEDIAL TREATMENT of STROKE SEQUELAE

Drug-based management with the help of nootropic drugs is one of the primary ways of treating stroke sequelae in children [41-46]. Mixed remedial treatment of stroke sequelae in children includes drug-based therapy alongside with medical rehabilitation (kinesitherapy, massage, mechanotherapy, physiotherapy, drug-based treatment), psycho-pedagogical and speech correction, social and environmental adaptation.

Drug-based therapy

Deanol aceglumate (Nooclerine by PIC-Pharma, Russia) is a nootropic drug of combined effect that is structurally similar to gamma-aminobutyric acid (GABA) and glutamine acid. It is recommended to administer the drug to over-10 children [41-43]. Being an indirect activator of the type III metabotropic glutamate receptors and a precursor of choline and acetylcholine, the drug impacts neuromediator metabolism in the CNS. It wields neuroprotector activity, induces

energy supply to the brain, enhances resistance to hypoxia, improves glucose uptake by neurons, and modulates the deintoxication function of the liver [41, 42].
Studies have shown that the drug is most therapeutically effective when treating asthenia (100%), asthenodepressive conditions (75%), and adynamic depressive disorders (88%), while increasing the behavioral activity in general and improving general tonicity and mood [43-46].
A study has identified a positive distinct nootropic effect of the drug, as well as its mild stimulation effect. The study involved 52 7-16 year-old children and was aimed at researching efficiency of the drug and tolerance thereto in cases of borderline neuropsychic disorders associated with residual-organic asthenic and neurotic deficiency of the CNS. Effects of the drug included the following: alleviation of asthenia, anxiety, emotional lability, sleep disorders, and enuresis in 83% of the patients. 80% of children had their attentiveness improved, auditory verbal memory augmentation was observed in 45.8%, visual image memory augmentation – in 67%, and enhanced memorization – in 36%. The antiasthenic and psychostimulating effects were not accompanied by psychomotor disinhibition and affective irritability [47]. Deanol aceglumate is listed in the Standards of the Russian Federation on specialized medical care and may be administered to treat organic dissociations (including symptomatic ones), mental disorders, depression and anxiety disorders [11, 12]. It has also been discovered that the drug has a positive impact on the visual analyzer and enhanced the functional activity thereof [48-49].
Experimental studies have shown that deanol aceglumate is highly effective when used for managing hypoxic conditions, disorders of cerebral hemodynamics and metabolism in the setting of ischemic and reperfusion brain injury [50, 51].
Therefore, results of numerous studies indicate that deanol aceglumate is an effective and safe drug that may be used to treat asthenic and asthenodepressive conditions, as well as cognitive and behavioral disorders of different genesis in children.
Another nootropic pluripotential drug that combines neurometabolic, neuroprotective, and neurotrophic effects is **hopantenic acid** (Pantogam by PIC-Pharma, Russia) [52-54]. The advantage of this drug is that it can be supplied both as pills and 10% syrup [53], which allows using it to treat neonates suffering perinatal stroke, as well as older children suffering stroke sequelae. Hopantenic acid (natural GABA metabolite) drug is an effective combination of minor psycho-stimulation, mild sedative, antiparoxysmal and deintoxication effects [53-53]. The drug is listed in the clinical guidelines on CP treatment (2014), as well as in the Federal Standards of the Russian Ministry of Health on Medical Treatment of organic disorders (including symptomatic ones) and psychic epilepsy-associated disorders [54]. The primary mechanisms of hopantenic acid is a direct impact on the $GABA_b$-receptors, potentiation of GABAergic inhibition in the CNS, regulation of neuromediator systems, stimulation of metabolic and bioenergetic processes in the nerve tissue, as well as reduction in the level of cholesterol and β-lipoproteids in the blood [52].
The spectrum of clinical application to treat stroke sequelae in children includes:
- cognitive disorders, including psychospeech retardation, speech disorders, early post-surgery cognitive dysfunction;
- locomotor disorders, delayed locomotor development; hyperkineses (the drug can be used for prolonged monotherapy [up to 4 months] or as a part of combined therapy that includes Tiapridal), management of extrapyramidal adverse effects of neuroleptic therapy;
- epilepsy. The drug can be used as a part of mixed therapy, as it wields an antiparoxysmal effect and does not lower the convulsive readiness threshold;
- neurotic and neurosis-like disorders, emotional and behavioral disorders;
- asthenic syndrome, reduced mental and physical performance capacity (especially in the setting of prolonged rehabilitation);
- vegetative dysfunction syndrome, including sleep disorders;
- pain syndrome. The drug is used as a part of mixed treatment of cervicalgia and cephalgia [53-60].
It has been shown that it is efficient to administer hopantenic acid to children whose medical history contains perinatal hypoxic-ischemic injuries of the CNS while they are undergoing

complex rehabilitation after locomotor and cognitive disorders. The values of psychomotor activity and visual-motor coordination enhance by 10 to 45%, the short-term memory is improved by 20% to 40%, and the attentiveness value is increased by 30% [53, 55]. Positive impact of the drug on the duration and the structure of sleep in neonates affected by perinatal hypoxic-ischemic injuries of the CNS [56], as well as on the speech functions of children suffering alalia has been discovered [57]. Use of the drug to treat cognitive disorders in epilepsy-affected children facilitated attentiveness improvement in 28% of the children, memory improvement – in 21% of the children, behavioral improvement – in 24% of the children, headache alleviation – in 24% of the children, autokinetic organization and motor response time were improved in 29% of the children, and the movement precision quadrupled [58]. Patients taking hopantenic acid demonstrated a significant alleviation of anxiety, improvement of sleep and of the EEG background rhythm structure, as well as normalization of zonal differences.

Positive experience of using hopantenic acid to treat patients with mild cognitive disorders of vascular genesis has been demonstrated: subjective improvement of patients' status accompanied by relevant positive dynamics of cognitive tests ($p < 0.05$), which comprised frontal dysfunction tests, clock drawing, and generalization capacity. No adverse effects have been registered in any patient undergoing such treatment [61]. Research of EEG properties of the drug's pharmacological effect in patients with cerebral vascular pathology and residual organic disorders helped to identify an alteration of power spectrum in all EEG ranges accompanied by a relevant enhancement of alfa-wave connectivity between occipital regions and central, midtemporal and posttemporal zones of the left hemisphere, whilst the slow wave connectivity between the left frontal area and ipsilateral cerebral regions degraded [62]; this indicates an improved organization of bioelectrical cerebral activity in patients suffering cerebrovascular diseases.

Mechanotherapy

Mechanotherapy is an important remedial treatment technique used to treat stroke sequelae. It is based on application of different training and specialized devices during rehabilitation. According to Supplement 1 (Standard for Equipment of Inpatient Rehabilitation Units to Treat Patients with CNS Function Disorders) to the Russian Federation Healthcare Ministry Order No. 1705 of December 29, 2012 (Organization of Medical Rehabilitation), remedial treatment units shall be equipped with the following:

- reflex-load devices (Gravistat-like suits);
- devices for robotized mechanotherapy of upper and lower limbs;
- biological feedback systems (BFS) for ambulation and equilibration recovery;
- training devices for enhancement of motion strength and volume in the appendicular joints;
- BFS for passive and passive-active mechanotherapy;
- equipment for recovery of small muscle strength (mechanized device for recovery of active finger motions);
- equipment for kinesiotherapy with bodyweight unloading;
- equipment for recovery of motion activity, limb motor coordination, daily activities and self-care. Such equipment ought to provide an ability to estimate functional capacities by means of interactive software, etc.

In recent years, the dynamic proprioceptive correction has come into use when treating patients suffering different NS disorders including stroke sequelae. This treatment employs special suits like Adeli, Gravistat, Regent, etc. [25, 31, 38, 63-68].

The primary effects of such treatment are as follows: enhancement and normalization of the disordered afferent proprioceptive stream; provision of graduated compression load along the long body axis; correction of positions of certain locomotor system segments alongside with normalization of knee-joint and ankle-joint angular ratios, which results in an improved sustaining of erect posture, motor function improvements, reduction of contractures and

deformations of lower limb joints; remodelling of interaction between sensory systems with visual analyzer becoming more important in erect posture regulation; and improvements of cognitive functions (including speech) [25, 31, 38]. The primary indications for using dynamic proprioceptive correction are as follows: cerebral palsy; long-term sequelae of minor, moderate, or severe head injuries; long-term post-stroke treatment; long-term sequelae of infectious inflammatory CNS diseases (meningitis, encephalitis). Counterindications of dynamic proprioceptive correction are as follows: age (not applicable to under-3 children); peracute and acute stroke phase; instability of liquor, hemodynamic, and hemocoagulation parameters; presence of apparent EEG alterations; fibrillation episodes; refractory AV-block; vegetative dysfunction with violent fluctuations of arterial pressure; diabetes; syncopal conditions; paroxysm syndrome; violent EEG epichanges; hip joint pathology; spinal column diseases; and somatic pathology in the exacerbation phase.

It has been shown that when dynamic proprioceptive correction is used during the later remedial or residual stroke phase, the patient's motor stereotype is gradually normalized as early as after 4 or 5 treatment sessions. Normalization is apparent at the end of the first treatment course. Steady stabilization of erect posture and improvement of motor functions were observed in 72.5% of patients suffering hemiparesis associated with acute cerebral circulation disorder. The Wernicke-Mann posture reduced, as well as muscular spasticity and severity of leg paresis; deep sensitivity recovered. The patients became capable of unassisted walking; their self-care capacities improved; the function of the paretic limb became better. Improvement of neuropsychological parameters in patients affected by motor afferent-efferent aphasia, who did not attend additional SLP sessions was observed; they became capable of uttering syllables and separate words. Patients with sensory aphasia became capable of better speech comprehension and of better task performance (especially in terms of daily activities) [67, 68]. In 20% of patients, the apparent positive trends acquired when treated with the Adeli suit developed further after dismissal from an inpatient unit [68].

Based on a space prototype, plantar supportive load simulator Corvit by LLC Aerospace Medicine Center, Moscow has been proven efficient as means of post-stroke rehabilitation. The simulator is designed to rehabilitate motor disorders associated with reduced or long-absent supportive load; to model the sensory image of gait in the mode of physiological evolution-anchored gait cyclogram; to potentiate reflex mechanisms of the gait; and to activate motor centers of spinal or higher organization as early as during bed immobilization of patients [69]. It has been shown that functional MRI, where sensomotor passive paradigm is used to imitate supportive gait load generated by Corvit, identifies massive activation of primary and secondary sensomotor cortex that participates in locomotion control. This can be a primary mechanism of motion disorder compensation [69].

Use of robotized mechanotherapy set MotionMaker by Swortec S.A., Switzerland, seems to be a promising tool for rehabilitation of children with stroke sequelae. It is the first device for remedial treatment of patients with paresis and plegiae that combines robotized motor activity with functional electrical stimulation and closed loop electrical stimulation technology. The sensors the robot is equipped with send information on the posture and the strength required for modulation of muscular contractions to the control device for the entire duration of the motion. Paralyzed muscles are involved in this process even if autokinetic movements are not controllable. Researchers at the Scientific Research Institute of Pediatric Infections of the Federal Biomedical Agency, St. Petersburg, have used MotionMaker to treat children suffering different NS diseases. Thereby, reduction in muscular hypertonicity, increased induced muscular strength (up to 400%), improved blood circulation and limb sensitivity has been identified. MotionMaker System is designed for patients suffering strokes, spinal cord injuries, traumatic cerebral injuries, cerebral palsies of different etiology, and multiocular sclerosis.

The Lokomat System by Hocoma, Switzerland, is easy to integrate into the clinical process. It enables physicians to carry out locomotor therapy by means of robotized orthoses on a treadmill, which provides for intensive training of patients suffering stroke, CP or other neurological conditions accompanied by lower limb paralysis [70]. Studies of the mechanisms of functional

mobility improvement involved 141 patients with post-stroke hemiparesis, who were training using the robotized Lokomat system. Formalized clinical scales, such as Fugl-Meyer, Modified Ashworth scale and Perry mobility scale were put into use as well as visual locomotion analysis alongside with analysis of intraarticular and interarticular cinematics before and after training. The studies have shown that the primary cause of increased walking mobility is improvement of gait parameters, both temporal (duration of the stance phase and the swing phase) and cinematic parameters (flexion/extension and abduction/adduction amplitude of the hip joint, as well as the angular speed of flexion/extension of the knee joint, and that of abduction/adduction of the hip joint). It has also been identified that use of the system to treat patients suffering post-stroke hemiparesis reduces the intensity of pathological locomotor synergies, which are known to have a negative impact on the walking speed and gait quality of the stroke survivors [70].

Physiotherapy

Different physiotherapy techniques are used to rehabilitate patients with stroke sequelae. Those include: electrophoresis, electrical myostimulation, paraffine-ozokerite and mud application, as well as use of alternating magnetic field; transcranial magnetic stimulation used to correct spasticity is a promising technique as well [71].

CONCLUSION

Thus, early and comprehensive diagnosis of stroke sequelae in children and proper and timely remedial treatment significantly increase efficiency of complex medical and social rehabilitation, which helps to reduce severity of disability, facilitates social adaptation and enhances life quality of the patient and their family.

CONFLICT OF INTEREST

The authors have declared absence of reportable financial support / conflict of interest.

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