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Abstract

Using infrared thermal imaging, 31 children aged 4-7 years with spastic forms of cerebral palsy were assessed. We provide detailed account of the temperature distribution and its dynamics under a motor load on the spastic muscle groups. The hemiparesis group has temperature asymmetries due to its decrease on the affected side. In the diplegia group there is an inversion of the normal distal-proximal temperature gradient on the limbs. Moderate physical load leads to the enhancement of the initial thermal anomalies. The study suggests how thermal imaging can be used for assessing the results of treatment of patients with cerebral palsy.

Introduction

Cerebral palsy (CP) affect on the neuromuscular system is manifested in spasticity, contractures, pain syndromes, muscle weakness, loss of selectivity, impaired postural control, pattern, and impaired standing balance [1]. One of the promising diagnostic methods for motor disorders is the measurement of skin temperature using thermal imaging. The methods for assessing the functional state of affected muscles and monitoring the effectiveness of rehabilitation measures in patients with CP using thermal imaging have been developed by a number of researchers [2,3]. However, the more detailed description of the temperature manifestations of spasticity in CP is still required. There is not enough data on the mechanisms of the formation of pathological thermopatterns with the relation to the degree of movement disorders. Also the data obtained in small heterogenic patient samples is often contradictory [4]. This determines the relevance of the methodological improving of thermal imaging research in children with CP to improve the quality of diagnostics and treatment of this condition.

Methodology

The study includes 31 patients with CP and functioning at Gross Motor Function Classification System (GMFCS) levels I or II aged 4-7 years old. CP was identified using ICD-10 codes G80.1 – spastic diplegia (17 children in total with 12 patients with lower paraparesis, 5 with upper paraparesis), G80.2 – hemiplegic form (14 children). Nine children with out disabilities of the same age served as the control group. All the children underwent an initial examination at the University Hospital in 2017. The study was approved by the local ethics committee of the Volga Research Medical University of the Ministry of Health of Russia (protocol No.4 from 03/29/2017). Informed consent was obtained from parents and/or the legal guardians.

The thermal image was observed by a thermo-tracer (NEC San-ei, TH-9100, Japan) with a temperature resolution of 0.06K. Our own active infrared thermal mapping technique has been applied [5]. The technique includes the registration of thermal maps of 67 regions of interest (ROIs) on the trunk, upper and lower limbs, and face, before and after the motor load. If necessary, additional sighting examined the fingers. Standard protocol complex biomechanical testing served as a functional motor load for all groups of children (including the control group).

For data processing and analysis we used MS Excel 2010 and Statisitica 12 software, and RStudio integrated development environment.

Results and discussion

Absolute temperatures and distal-proximal gradient (DPG).

The distribution and dynamics of temperatures on the face proved to be uninformative. In the thermal patterns on front surface of the trunk (chest and anterior abdominal wall) we also found no significant deviations from the norm. An analysis of thermal patterns of back revealed a distinction of the diplegia group from the control and the hemiparesis groups in the form of a temperature difference between the thoracic and lumbar regions above 0.5°C; the greater temperature difference, the more severe paresis at the corresponding level (in 5 patients – upper paraparesis, in 12 – lower).

The distribution and dynamics of temperatures on the limbs were of the greatest theoretical and practical value. In the control group, after a 10-minute adaptation in all ROIs, thermal maps were typical of children of this age both initially (before the load) and after the load. In the diplegia group, initially, there was a distinctive DPG inversion in the front surface of the lower limbs, namely shin/foot segments with increase in temperature to distal direction, and on the inner surface of the upper limbs in the shoulder/forearm segments, not prevent in the control group. However this symptom was unstable under the load. In the hemiparesis group, the initial scatter of the absolute temperature values was 29.6 to 35.7°C on the lower limbs, 30.5 to 35.0°C on the upper limbs with single cases of DPG inversion, which was not significantly different from the control group; the application of the load did not influence these ratios.

There are significant differences in initial absolute temperatures on the following ROIs (Mann-Whitney criterion): hemiparesis and the control – the back of the wrists; diplegia and control – none; hemiparesis and diplegia – the back of wrists and the projection of the ankle joints.

After the load, there are significant differences in the following ROIs: hemiparesis and control – none; diplegia and control – the back-inner surface of the shin; hemiparesis and diplegia – the projection of the ankle joints and the back-inner surface of the shin. The dynamics at the stages is significant for evaluating the compensatory muscle resources.

Thermal asymmetry (TA).

Initially, TA in the control group did not exceed 0.4°C in all segments and in all pairs of symmetrical ROIs. After the load, the temperature symmetry also did not change significantly showing independence from changes in the absolute temperature values, especially in the distal limb segments. The diplegia group differed little in terms of TA from the control group. A sharp distinction from the other two groups was found in the hemiparesis group: a decrease in temperature on the affected side, emphasized in the projection of the most suffering muscle groups. After the load, an increase in TA was recorded in these patients, while in a number of ROI with initial values within typically normal limits, the compensation was disrupted. The pattern of these changes is promisingly correlated with problem muscles, which is especially important in the demanding conditions of activity and the environment. The number of ROIs on the limbs with a significant difference in TA values between groups at least for one measurement stage (given the absolute temperature values, the modulus of these values, and the sign weights) was: Control/Hemiparesis – 16 ROI, Control/Diplegia – 2 ROI, Diplegia/Hemiparesis – 22 ROI.

Conclusion

Thermal imaging is an objective method for assessing the functional state of the thermoregulatory system, reflecting the degree of motor impairment in the form of deviations from the normal thermal pattern of the skin over affected muscle groups and temperature reactions to moderate dosed motor loads.

The study revealed thermal imaging markers of the functional state of spastic muscles determined by the adaptive-compensatory reserves of their blood supply and thermoregulation. Patients with hemiparesis (G80.2) have characteristic TA on the affected side. For diplegia (G80.1), the inversion of normal DPG on the limbs is present. The intensity of thermal anomalies is individual, the general pattern is the decrease in temperature on the affected side at the corresponding level. Moderate motor load enhances thermal anomalies in both groups by further decrease in temperature in the projection of the affected muscles.

Thermal imaging allows to evaluate the pattern and degree of ischemic disorders in the muscles. Therefore the method can be potentially used for the selection of target muscles during botulinum therapy, and for the treatment evaluation in patients with CP. We consider the goal of rehabilitation measures in patients with CP to be the improvement of the symmetry and normalization of DPG on the limbs. In our opinion, the progress towards this goal will reflect the positive dynamics in the formation and consolidation of the correct motor stereotypes. The degree of deviations from the normal values of TA and DPG on the limbs at rest and after the motor load can serve as predictor of the success or failure of the planned neurorehabilitation programs, as well as serve as initial indicators for classification of the degree of movement disorders in spastic CP (differential diagnosis).

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