Recording of Amplitude-Integrated Electroencephalography, Oxygen Saturation, Pulse Rate, and Cerebral Blood Flow during Massage of Premature Infants

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Abstract

Objective Stimulation of the nervous system plays an important role in brain function and psychomotor development of children. Massage can benefit premature infants, but has limitations.

Study Design The authors conducted a study to verify the direct effects of massage on amplitude-integrated electroencephalography (aEEG), oxygen saturation (SaO_2), and pulse analyzed by color cerebral function monitor (CCFM) and cerebral blood flow assessed by the Doppler technique.

Results The amplitude of the aEEG trend during massage significantly increased. Massage also impacted the dominant frequency δ waves. Frequency significantly increased during the massage and return to baseline after treatment. SaO_2 significantly decreased during massage. In four premature infants, massage was discontinued due to desaturation below 85%. Pulse frequency during the massage decreased but remained within physiological limits of greater than 100 beats per minute in all infants. Doppler flow values in the anterior cerebral artery measured before and after massage did not show statistically significant changes. Resistance index after massage decreased, which might provide greater perfusion of the brain, but this difference was not statistically significant.

Conclusion Use of the CCFM device allows for monitoring of three basic physiologic functions, namely aEEG, SaO_2, and pulse, and increases the safety of massage in preterm infants.

Keywords
- premature infants
- massage
- color cerebral function monitor

Physiotherapy is a recognized technique applied in multiple stages of treatment and neurodevelopmental therapy for newborn infants. Massage is one physiotherapy method used in this setting. Scientific evidence confirms the value of massage and supports its implementation for the treatment of premature infants.[1–3] Massage by stimulation of receptors can affect functional development of the nervous system. Stimulation of the nervous system is important both

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for stimulating brain function in the context of psychomotor disability and minimizing the potential risk of developmental disorders, especially in premature babies.[4–7] One of the most difficult problems in premature infants is optimization of stimulation methods. Massage can be beneficial but has limitations resulting from the child's general health condition and ability to tolerate touch. Infants who are premature and clinically unstable and have severe medical conditions and/or extremely low body weight cannot tolerate massage. In these infants, massage may lead to desaturation, bradycardia, electroencephalography (EEG) disturbances, and changes in cerebral blood circulation. Massage can also have positive effects in premature infants on bioelectric activity of the brain, cardiovascular circulation, cerebral blood flow, and oxygen saturation (SaO_2). Interest in massage is based on the assumption that its use can improve outcomes of premature babies and full-term newborns, accelerate maturation and growth, reduce iatrogenic effects of prolonged intensive care admission, shorten the duration of hospital stay, and reduce treatment costs. However, thus far many of these benefits have not been documented and require further research.[2,3,8] We conducted a study to determine the direct effects of massage on amplitude-integrated EEG (aEEG), SaO_2, and pulse using color cerebral function monitor (CCFM) and cerebral blood flow assessed by Doppler.[1,9–13]

Aims of Study

The working hypothesis is that massage does not cause abnormalities in aEEG recording, SaO_2, pulse, and cerebral blood flow that may be indicative of pathological processes. Also, massage cannot be assumed safe for all premature infants. The authors have not studied extremely low-birth-weight neonates and ill neonates.

The specific objectives of this work are to assess the following parameters before, during, and after massage: amplitude and shape of the aEEG trend and the dominant waves of amplitude and frequency, SaO_2 at the upper right limb, and pulse on the upper right limb. The Doppler values, systolic velocity (Vs), diastolic velocity (Vd), resistance index (RI), and pulsatility index (PI) in anterior cerebral artery were assessed before and after massage. Interactions between aEEG, SaO_2, and pulse are investigated.

Materials and Methods

Patients

Thirty-five premature babies treated at the Department of Newborn Diseases, Pomeranian Medical University received massage.

Electrical brain function, hemoglobin SaO_2, and pulse on the right upper extremity were simultaneously recorded before, during, and after massage with the CCFM. Before and after massage, Doppler cerebral blood flow was evaluated with the En Visor Philips device (Andover, MA). The study enrolled clinically stable preterm infants between 28 and 37 weeks' gestation. Twenty-two infants were born before 32 weeks of gestational age (GA) and the rest of 17 infants after 32 weeks of GA. The average infant age on the day of massage was 24 and 18 days for presented groups, respectively. The massage lasted ~17 minutes. The procedure was performed 30 minutes after feeding when the infant was quiet and relaxed. Exclusion criteria were skin trauma, infection, respiratory disorder, circulatory instability, neurological disorder, or active retinopathy of prematurity. Four children were excluded from the study group after the start of massage because of SaO_2 desaturation below 85%, which is considered a consequence of intolerance to the stimulus.

Methods

During the massage, aEEG, SaO_2, and pulse were monitored with the CCFM (Elmiko, Warsaw, Poland), which allows the recording of long-term two- or four-channel EEG, two-channel aEEG trends, pulse rate, and preductal SaO_2 from the right arm, assuming that oxygenation levels in the right hand show a linear correlation with the level of oxygen in brain tissue.[9] CCFM allows long-term evaluation of recordings to determine EEG dominant waves and their frequency, amplitude, and shape. Below the EEG trace, the aEEG, SaO_2, and pulse rate trends are visualized (►**Fig. 1**). Evaluation of the sequence of events allows elucidation of the etiology of seizures as well as the assessment of medical interventions. The dependence of the amplitude and frequency of individual EEG waves can be analyzed using Fourier transformation in cases of clinical and neurophysiological events. The line running vertically through the trends of the EEG, SaO_2, and pulse enables the assessment of the sequence of events and also displays the values of the instantaneous EEG amplitude curve (►**Fig. 2**). It is feasible to arbitrarily select medical events and their detailed and ex post analysis combined with video pictures.[10,14]

Doppler ultrasonography was performed using a 12-MHz probe placed near the frontal fontanel to explore the anterior cerebral artery at an angle as close to 0 degrees as possible. Measurements were performed after installing the CCFM electrodes before and after massage. The Shantal massage proposed by Leboyer is used prophylactically to stimulate development in infants during the early stage of life.[15] This massage by stimulation of receptors influences the neurohormonal mechanisms in infants. The procedure uses two classical techniques of massage, stroking and rubbing. Massage was performed by the same masseur, adjusted for the intensity, pace, and duration. Massage involved the entire body, including the chest, upper limbs, abdomen, legs, back, and face. Every movement in the massage was repeated three to five times, except for those involving the head because of technical limitations resulting from electrode placement. The F_3 and F_4 sites were chosen to avoid artifacts in massage of the rest of the body, because the infant was lying at the back and left and right lateral position during procedure. Massage was performed by the therapist in the presence of the mother, who was informed that the massage could be performed independently during the hospital stay and after discharge. The local Bioethics Committee approved this study (KB-0080/125/09). Inform consents were obtained from all parents.

Figure 1 Trends in amplitude-integrated electroencephalography, oxygen saturation, and pulse with video camera recording and instantaneous values via color cerebral function monitor.

Results

The amplitude of aEEG during massage range (13 to 172 µV) increased significantly from median 54 to 100 µV and returned to baseline values of median 50 µV after massage (►**Fig. 3**). Massage of premature infants also affected the dominant frequency delta waves. Frequency significantly increased during massage and returned to baseline after treatment (►**Fig. 4**). Also, the differences in the amplitude of δ, θ, α, and β before massage compared with during massage and during massage compared with after massage were statistically significant ($p < 0.005$; ►**Figs. 5**, **6**, **7**, and **8**). Hemoglobin SaO_2 decreased significantly during massage, after massage exceeded the initial level (►**Fig. 9**). Pulse frequency remained within physiological limits during and after massage (►**Fig. 10**). There were no statistically significant changes in Doppler measurements of the anterior cerebral artery before and after massage in terms of Vs, Vd, PI, and RI (►**Fig. 11**).

Discussion

Increased amplitude of aEEG during a massage is recognized as a reaction to a stimulus, because values reverted to premassage values after the procedure (►**Fig. 3**). Changing the amplitude of aEEG recording during sleep and wake is one criterion for nervous system maturation in premature infants. Thus massage may stimulate brain electrical activity, which contributes to maturation.

Analysis of neonatal EEG in active status indicates that the δ wave activity is dominant. In newborns, there is a tendency toward increased EEG amplitude and decreased frequency of deep sleep observed during massage (►**Figs. 4** and **5**). During active sleep, neonates show reduced amplitude and increased frequency.[16] The increase in δ amplitude also applies to α, θ, and β waves (►**Figs. 5**, **6**, **7**, and **8**). Hemoglobin SaO_2 decreased significantly during massage (►**Fig. 9**). After massage, SaO_2 increased and exceeded the initial level; however, the difference was not statistically significant. In four premature infants, massage was discontinued due to desaturation below 85%. Massage in premature infants, therefore, is limited by the potential for hypoxia and should be performed in conjunction with pulse oximetry to avoid iatrogenic complications.

Pulse frequency during massage decreased but in all cases remained within physiological limits (greater than 100 beats per minute). After massage, pulse returned almost to baseline (►**Fig. 10**).

Doppler flow in the anterior cerebral artery, Vs, Vd, PI, and RI measured before and after massage did not show statistically significant changes. A drop in the RI after massage may result in changes in perfusion, but this difference was not statistically significant (►**Fig. 11**).

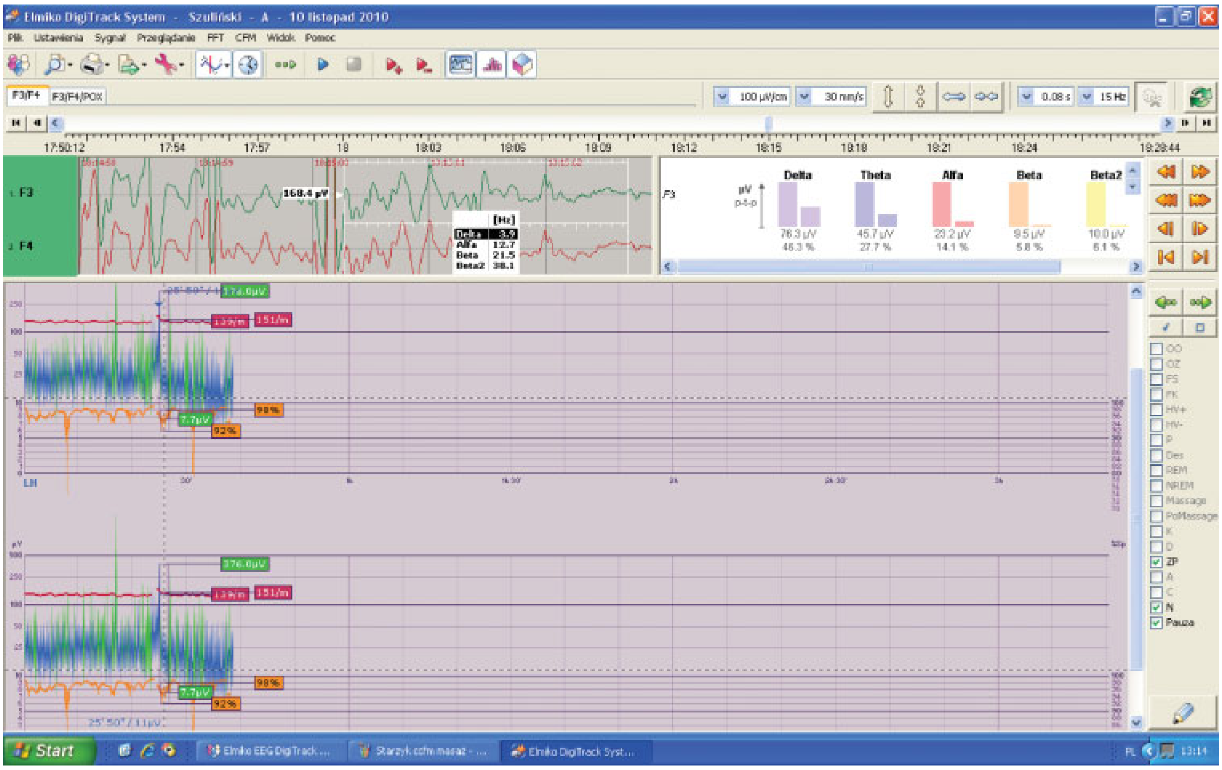

Figure 2 Analysis of electroencephalography (EEG) waves from the left and right hemispheres, waves of the dominant frequency of the δ 2.0 Hz, and the frequency of the other waves. Trends in amplitude-integrated EEG (blue and green), oxygen saturation (orange), and pulse (red) from left and right hemispheres of the brain.

CCFM allows for monitoring of the basic functions of brain activity (aEEG), breathing (SaO_2), and circulation (pulse) and documents disturbances in the form of EEG abnormalities, desaturation, or bradycardia. These data can be used to determine the sequence and severity of clinical events. CCFM provides instantaneous values for all of these parameters. In addition, EEG waveform from the left and right hemispheres can be analyzed at any time recorded. Doppler measurement of blood flow in the cerebral vessels provides an indirect assessment of blood supply to the brain.

Anterior cerebral artery Doppler studies suggest that during the massage there is no disturbance in cerebral blood circulation. There were no heartbeat disorders and specifically no case of bradycardia during massage. Changes in EEG amplitude involving an increase in the aEEG trend and increased frequency of the dominant δ waves suggest that

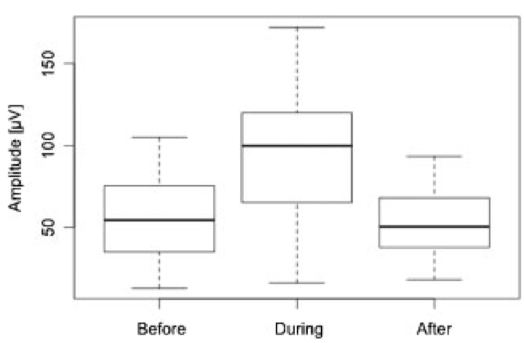

Figure 3 Amplitude-integrated electroencephalography amplitude before, during, and after massage: before massage compared with during massage ($p < 0.001$), during massage compared with after massage ($p < 0.001$).

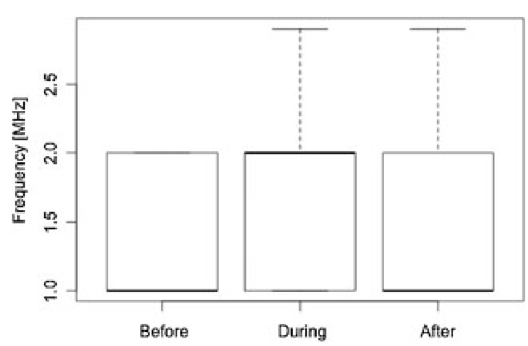

Figure 4 Frequency of δ waves before, during, and after massage: before massage compared with during massage and during massage compared with after massage ($p < 0.05$).

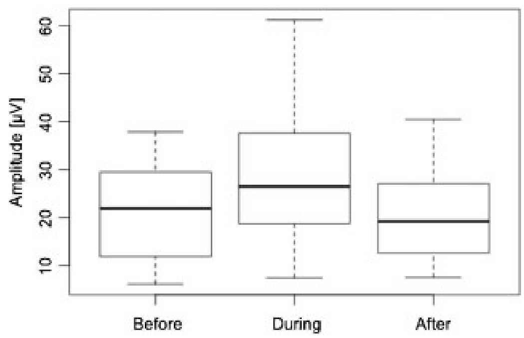

Figure 5 Amplitude δ waves prevailing before, during, and after massage: before massage compared with during massage ($p < 0.005$), during massage compared with after massage ($p < 0.005$).

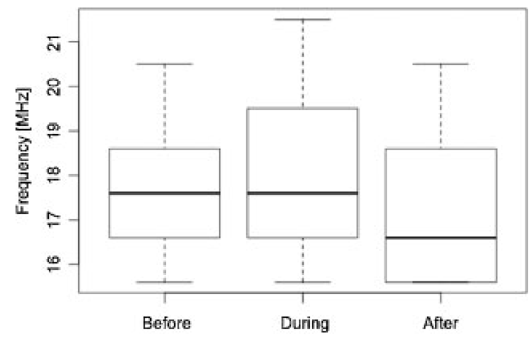

Figure 8 Amplitude of β waves before massage compared with during massage ($p < 0.001$), during massage compared with after massage ($p < 0.001$), and before massage compared with after massage ($p < 0.05$).

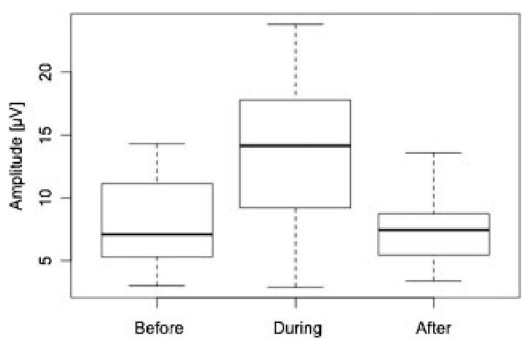

Figure 6 Amplitude of α waves before, during, and after massage: before massage compared with during massage ($p < 0.001$), during massage compared with after massage ($p < 0.001$).

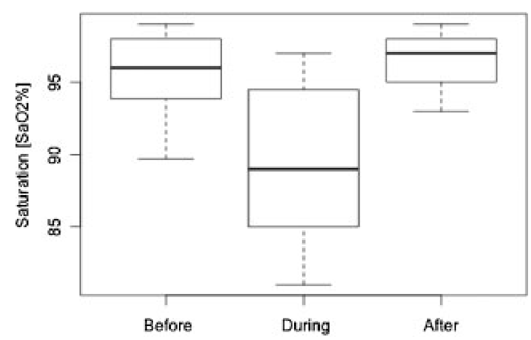

Figure 9 Oxygen saturation (SaO_2) at the upper right limb before, during, and after massage: before massage compared with during massage ($p < 0.001$), during massage compared with after massage ($p < 0.001$), before massage compared with after massage ($p < 0.05$).

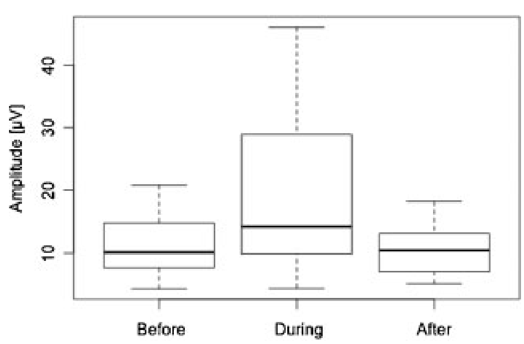

Figure 7 Amplitude of θ waves before, during, and after massage (not significant).

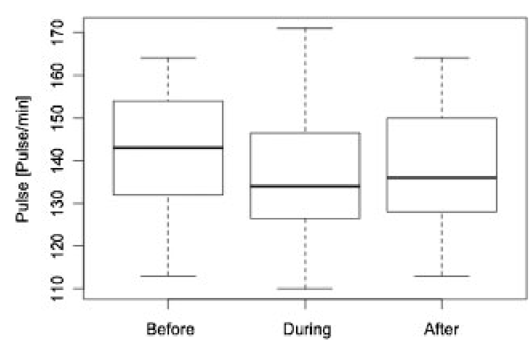

Figure 10 Pulse before, during, and after massage: before massage compared with during massage ($p < 0.05$); during massage compared with after massage and before massage compared with after massage (not significant).

it affects the stimulation of brain activity; relaxation is affected by such phenomena as occur in infants during sleep.[16–18]

Massage therapy has many putative benefits. Reduction of neurobehavioral deficits during early development is the goal of therapeutic and prophylactic therapy in preterm and full-term neonates. Neurodevelopment stimulation alleviates the potential risks of premature birth. Massage increases insulin concentration in the blood, leading to accelerated weight gain compared with children not massaged. It is also associated with a shorter hospital stay, reduced exposure to nosocomial infections, fewer iatrogenic complications, and lower cost of treatment. Furthermore, massage reduces the level of stress hormones, which affects sleep and stimulates the

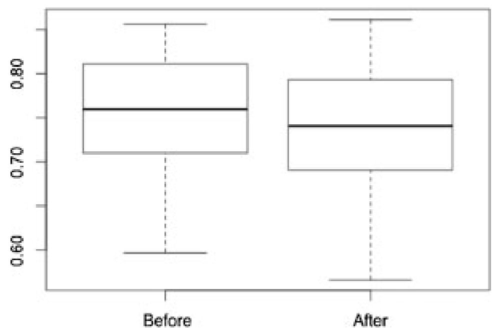

Figure 11 Resistance index in arteria cerebral anterior before massage compared with after massage (not significant).

development of neurobehavioral mechanisms, which are essential to achieve full potential. Although there are many benefits of massage in premature infants, there is a fear of adverse effects including desaturation and impaired cerebral blood flow, triggering pathological electrical activity in the cerebral cortex. Therefore, vital functions should be monitored during the massage of premature infants. The heterogeneity of the group is the limitation of our study.

Conclusion

1. Massage alters the aEEG recording characteristic of the newborn during relaxation.
2. Massage does not interfere with premature cerebral blood flow.
3. To maintain safety during massage, SaO_2 should be monitored in premature infants.
4. Massage has no negative impact on pulse frequency in premature infants.

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