

ORIGINAL ARTICLE

Changes in Cerebral Function Associated with Oral Pain Caused by Dentures

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Objective measurement of pain may be useful for dental diagnosis and therapy. The purpose of this study is to measure reactions to pain in the cerebral cortex during dental treatment using NIRS (Near Infrared Spectroscopy), and to assess potential applications of this measuring system in the field of dentistry. Oxygen exchange in the cerebral cortex (oxygenated Hb, deoxygenated Hb and total Hb) was measured to indicate brain function, with and without pain. Also, measured data were mapped using a COE (Cerebral functional mapping of Oxygen Exchange) system. We obtained the following results: (1) reactions in the cerebral cortex apparently related to dental pain were measured, (2) these reactions varied associated with the degree of pain, (3) these measurement responses were quick and reactions could be shown within a few seconds during an event, and (4) the reactions also disappeared quickly after the pain disappeared. The results of this research indicated that this measuring system of brain function has a high potential for use in dentistry.

Key words: oral pain, cerebral function, oxygen exchange, near-infrared light

Introduction

Most dental diseases can cause oral pain, and most dental treatments also cause pain. Since pain provides important information about dental disease and must be considered in planning treatment, the objective and quantitative measurement of oral pain is considered to be useful in dental diagnosis and treatment. However, until now, there has been no way to measure the location, kind, and degree of pain objectively.

Pain is transmitted through the nerves to the brain. It is considered that the localization of pain

may be reflected as a cerebral function, and degree of pain may be felt at same area. It seems likely that the location and degree of pain may be reflected by the location and degree of cerebral function. It is therefore possible that measurements of human cerebral function during pain may reflect information about pain and brain. PET, fMRI and NIRS (Near Infrared Spectroscopy, a system for measuring brain function as changes in active oxygen exchange in the capillaries at the cerebral cortex, using the diffusion and scattering of near-infrared light through the scalp and skull) can be used to measure brain functions from outside the body in vivo.

The purpose of this study is to measure reactions to pain in the cerebral cortex during dental treatment using NIRS (Near Infrared Spectroscopy), and to assess potential applications of this measuring system in the field of dentistry. In this study, changes in cerebral function caused by oral pain were measured using NIRS imaging and displayed using COE, and changes in cerebral function related to the degree of pain and its disappearance were measured.

Materials and methods

The subject was a 72-year-old female patient who uses complete dentures. Oxygen exchange (oxygenated Hb, deoxygenated Hb, and total Hb) was measured (Shimadzu OMM3000 31-channels) to indicate brain function, with and without painful stimuli from the patient's dentures. Figure 1 shows the position of channels on an MRI image. Measurements were carried out 5 times in each condition, and averaged data were analyzed by the COE system.

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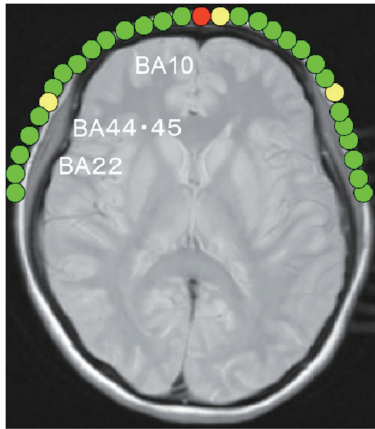


Fig. 1 Measurement positions shown in an MRI image of the brain.

Results

1. Changes in active oxygen exchange in the cerebral cortex

Changes in active oxygen exchange in the cerebral cortex with pain from dentures are shown in Figure 2 (oxy-Hb: red; deoxy-Hb: blue; total-Hb, green). The numbers in this chart are from measurement channels Ch1-31. Ch1 is located in Brodmann's area BA 22, Ch5-6 in BA 44-45, and Ch13-15 in BA 10. Ch 16 is located at center of the head (Fig. 1).

Major changes were observed when pain was felt in Ch 10-22. During the period when the patient was feeling the pain, total-Hb (green) increased markedly, and after the pain faded away, it decreased rapidly. These measurements are very sensitive, and changes in active oxygen exchange were measured within 2-3 seconds of the event.

Figure 3 shows changes in active oxygen exchange in the cerebral cortex when the source of pain was removed. In Ch10-20, although oxygen exchange was observed with the dentures in place, it was significantly less than that with pain, and rapid decreases in total-Hb were not observed.

2. Results of COE analysis

COE results with pain are shown in Figure 4. From left to right, they are: COE before the patient was feeling pain (0 s), feeling pain (4.0 s), just before the pain faded away (9.6 s) and after the pain faded away (11.0 s).

An increase in oxy-Hb (red) was observed in the right temporal region at 4.0 s. At 9.6 s, this area shows green because values for oxy-Hb and deoxy-

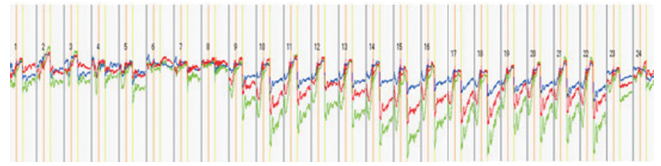


Fig. 2 Changes in active oxygen exchange with pain.

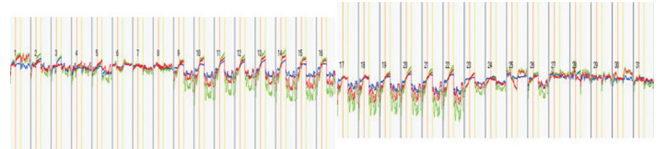


Fig. 3 Changes in active oxygen exchange without pain.

Hb were equal. Immediately after the pain faded away, at 11.0 s, an increase in oxy-Hb causes a change to blue in the temporal region.

No remarkable changes in COE results were observed in the temporal region during the period without pain.

3. Differences between changes in active oxygen exchange by measurement locations

Figure 5 shows changes in active oxygen exchange with pain in the left premolar portion of mandible, at Ch 7, located at BA 44-45 of the right side, Ch 15 located at BA 10 near the frontal region, and Ch 26 located at BA 44-45 of the left side.

With pain, major changes in total-Hb (green) were observed in all the channels. Oxy-Hb and deoxy-Hb exchange were the same at Ch 7, and oxy-Hb exchange was twice as much as deoxy-Hb exchange at Ch 15. Conversely, deoxy-Hb exchange was twice as much as oxy-Hb exchange at Ch 26.

Discussion

Several methods are available for measuring brain function. MRI produces images of brain activity, and PET, fMRI and NIRS imaging make it possible to observe blood dynamics in the brain. In clinical application, measurement of brain function should be noninvasive, be able to be used at bedside (or dental chair-side) and be sensitive in its response to events.

With NIRS imaging, cerebral functional changes are measured noninvasively, using near-infrared light through the scalp and skull. In addition, with this system, the optical probes for measuring

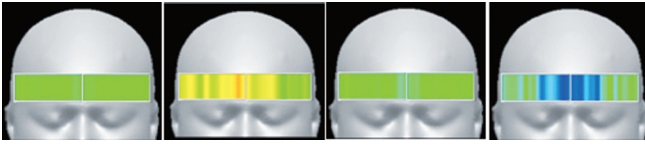


Fig. 4 Results of COE analysis with pain.

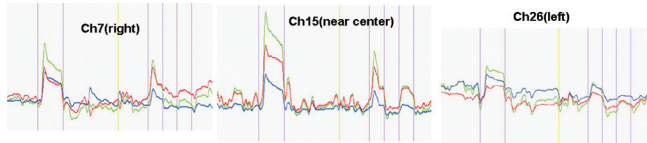


Fig. 5 Differences between changes in active oxygen exchange in different measurement locations.

are small, and large equipment is not required, as it is for MRI or PET. A further advantage is that the position of the body is not restrained in this method. Responses are very quick, and reactions were shown within 2-3 seconds of an event. COE is a system for displaying active oxygen exchange (FORCE) locally in the cerebral cortex with high spatial resolution and response.^{1,2} The principles of COE were developed by Kato, and COE is applied as an evaluation system to aid in medical rehabilitation and the education of children with handicaps.

1. Changes in active oxygen exchange in the cerebral cortex

The results of NIRS imaging showed major changes in active oxygen exchange over area from the temporal to the frontal region with oral pain: oxy-Hb increased while pain was felt and decreased immediately after release from pain. These major changes were not observed without pain. The same changes were displayed strikingly by COE. Without pain, no change was observed.

2. Differences between changes in active oxygen exchange in different measurement locations

The response format of cerebral function was

shown to differ by brain region during equal pain stimulation. Future research will be required to explain this phenomenon.

These are first results showing a relationship between brain function and oral pain.³ This pilot study indicates that the active area of the cerebral cortex depends on the degree and type of pain. Clinical application of this measurement will require further research to analyze the results of this study quantitatively, and to improve the measurement equipment specifically for dental use.

Conclusion

Reactions were measured in the cerebral cortex that were apparently related to dental pain. The following results were obtained from this study:

- 1) NIRS measurement response are quick, with reactions appearing within 2-3 seconds of an event.
- 2) These reactions also disappeared quickly after the disappearance of pain.
- 3) The response formats of cerebral function differ according to the location in the brain.

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