Alternations of hemodynamic parameters during Chinese cupping therapy assessed by an embedded near-infrared spectroscopy monitor

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Abstract: Cupping therapy is a promising method to cure or reduce the symptoms of some diseases including muscle pain/tendency/fatigue. Although the applications of cupping therapy have a thousand-year history in traditional Chinese medicine, the therapeutic effect of cupping is still questionable due to a lack of scientific evidence and the absence of physiological observations. In our previous study, we utilized near-infrared spectroscopy (NIRS) to assess the concentration change surrounding the cupping site and found a significant elevation in oxy-hemoglobin (HbO₂). To further investigate the therapeutic effect of dry cupping treatment, we embedded a NIRS sensor into a suction cup to monitor the hemodynamic changes including HbO₂, deoxy-hemoglobin ([Hb]) and blood volume on the cupping site in this study. Both a prominent elevation in [Hb] and a significant drop in [HbO₂] in the tissue of the cupping site were observed during cupping. We also observed similar hemodynamic changes during post-cupping, which may demonstrate how cupping therapy works for treatment. This study showed that the embedding of NIRS sensor in a cupping system could offer a better understanding of the mechanism of cupping therapy.

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1. Introduction

For more than a thousand years in China, cupping therapy has been widely used to relieve muscle pain and improve the general health condition [1–3]. Its principle therapy is based on the low negative pressure inside the cup that creates suction on the skin, which can induce local stasis of blood in the area mantled by the cup [4]. The detailed mechanism of cupping therapy has been introduced in ref [4].

In recent years, there has been an increase of studies on cupping therapy. Most of these studies were published in traditional Chinese medicine (TCM) related magazines [5–8]. The studies reported cupping therapy as a useful supplementary treatment to control symbols of illness, e.g., post herpetic neuralgia [6], fibromyalgia [1], and caner pain [7], as well as provide significant support during post-stroke rehabilitation [8]. However, the cupping therapy is still under suspicion of being a pseudoscience [9] due to few objective evaluation of treatment efficiency by modern scientific criteria. Therefore, an objective measurement such as near-infrared spectroscopy (NIRS) [10–12] are needed to provide evidence of cupping therapy from the perspective of modern science. NIRS is a promising developing technology that offers a noninvasive, real time, portable, relatively inexpensive method for hemodynamic measurements and have been validated in many realms for metabolic quantifications. Compared to other measurements such as PET, fMRI and ECG, NIRS places fewer limitations on the subjects and environment and was less susceptible to the interface such as motion artifacts. Therefore, we chose NIRS to monitor the metabolism of tissue.
In our previous study, we investigated the concentration changes in oxyhemoglobin ([HbO\textsubscript{2}]) and deoxy-hemoglobin ([Hb]) and the derived change in blood volume ([tHb]) surrounding the cupping site based on NIRS [13]. The results manifested the enhancement of oxygen uptake. To get more complete picture of the cupping therapeutic effect, in this study we used embedded NIRS monitor into a dry cupping system to detect hemodynamics within cupping region. We investigated the concentration changes in [HbO\textsubscript{2}], [Hb] and [tHb] on the acupoint of kidney in human subjects during the cupping treatment. Statistically significant hemodynamic changes were observed, revealing the inner mechanism of cupping therapy and complementing our previous research.

2. Methods

A home-made NIRS oximeter (Fig. 1(a)) with three wavelength LED light source (735, 805, and 850 nm) and an optical detector was engaged to detect hemodynamic changes in this study. Near infrared light was injected into tissue via a probe attached on the skin. The source-detector distance was set as 3 cm, allowing for larger than 1 cm penetration depth [14]. The changes of [HbO\textsubscript{2}] and [Hb] (\(\Delta[HbO_2]\) and \(\Delta[Hb]\)) are calculated from the light intensity variations using the modified Beer-Lambert law [15]. The changes of [tHb] (\(\Delta[tHb]\)) is calculated by \(\Delta[tHb] = \Delta[HbO_2] + \Delta[Hb]\). The sampling rate is 5 Hz and more details of the NIRS oximeter can be found in refs [16,17].

Conventional cupping kit (Fig. 1(b)) including a few cups and a mechanical exhauster was used for treatment. To embed the probe into the cup (Fig. 1(f)), we drilled a small hole on the tube wall. The wire connecting the probe and the control circuit go through the tube wall. The hole was then sealed by chemical glue to avoid air blowing. During the experiment, the probe was attached to the skin of participant with medical double-sided tape (Fig. 1(g)).

Thirteen healthy volunteers (aged 22~26 years, mean: 24.3 years) including 5 women participated in this study. None of the volunteers received any cupping or similar treatment within 6 months. Our experiment protocol (Fig. 1(c)) includes a 5 minutes baseline measurement, an 8 minutes cupping treatment, and a 6 minutes recovery measurement. A cup with embedded probe was attached on the participant’s acupoint of kidney (Fig. 1(d)). We chose this spot because cupping therapy at the acupoint of kidney can effectively relieve symptoms of lumbago according the TCM theory. For each treatment, the pressure inside the cup was kept constant at 0.075 ± 0.005 MPa under the inspection of the practitioner. The room temperature was maintained at 25°C and lights were remained off during the experiment. A telltale sign of cupping treatment, the red circle shown in Fig. 1(e), will appear after treatment and usually disappear in the next 3 days. The oxygenation data during the entire period of measurement was normalized to the baseline, i.e., the average data in the first 30 seconds. For statistical analyses, \(p < 0.05\) was set as the significance criteria for all T-tests, one-way ANOVA, and linear regression methods. False discovery rate (FDR) correction was made for all the p-values. This study was approved by the Human Subjects Institutional Review Board of Peking Union Medical College.
3. Results

The data collected from one male were excluded because of strong motion artifacts during treatment. The rest 12 measurements were subsequently analyzed in MATLAB. The Hemodynamic changes of a typical individual during treatment is showed in Fig. 2(a). An obvious drop in $\Delta[\text{HbO}_2]$ ($-6.10$ $\mu$M at maximum and $-5.87$ $\mu$M on average) and a dramatic elevation in $\Delta[\text{Hb}]$ ($9.62$ $\mu$M at maximum and $9.09$ $\mu$M on average) were observed during the cupping stage. The $\Delta[\text{Hb}]$ consequently has a mean elevation of $3.22$ $\mu$M possibly because that low air pressure took blood into the cupping site. After the cupping stage, $\Delta[\text{HbO}_2]$ increased and $\Delta[\text{Hb}]$ decreased as expected. During the post-cupping stage, the values of $\Delta[\text{HbO}_2]$ remains lower ($-3.49$ $\mu$M on average) and $\Delta[\text{Hb}]$ remains higher ($5.28$ $\mu$M on average) compared with the values of baseline. All the mean values were calculated over the stable period. The variations were significant compared with the baseline ($N = 12$, $p<0.02$) in T-tests for all parameters.
Fig. 3. The means and standard deviation bar of all measured hemodynamic parameters during the periods of baseline, cupping, and post-cupping. T-test results were shown by p-values.

Figure 2(b) shows the same trend in the grand-average response of 12 subjects for all hemodynamic parameters. The mean values of Δ[HbO₂], Δ[Hb] and Δ[tHb] are displayed respectively in the format of mean ± standard deviation (Fig. 3). During the cupping stage, the Δ[HbO₂] decreased by −4.19 ± 1.56 μM and the Δ[Hb] increased by 7.69 ± 1.89 μM, resulting in a 3.50 ± 1.27 μM change in the Δ[tHb]. The sustaining oxygenation changes were also observed after releasing air pressure in cup. In the post-cupping stage, the mean values of Δ[HbO₂], Δ[Hb] and Δ[tHb] were consecutively −1.92 ± 0.62, 3.20 ± 1.12 and 1.29 ± 0.67 μM. All T-tests between each two stages exhibit significant changes (p<0.05, N = 12; Fig. 3) in Δ[HbO₂], Δ[Hb] and Δ[tHb]. One-way ANOVA was performed to evaluate the difference among all stages for variable of hemodynamic parameters. Significances were found for all parameters (p<0.01), specifically, F (2,12) = 19.86 for Δ[HbO₂], F (2,12) = 16.91 for Δ[Hb] and F (2,12) = 15.28 for Δ[tHb].

Linear regression analysis was performed to investigate the correlation between the cupping stage and the post-cupping stage alternations. As shown in Fig. 4, significant correlations were found for [Hb] (p<0.01, R = 0.80), [HbO₂] (p<0.01, R = 0.76) and [tHb] (p<0.05, R = 0.69). Besides, all the scatters were below the line y = x, denoting that the oxygenation changes in the cupping stage were higher than the post-cupping stage.
To investigate the relationship between [Hb] and [HbO₂] during the cupping stage, we performed linear regression analysis on Δ[Hb] and Δ[HbO₂] time series for each subject (Table 1) and analyzed correlation between averaged Δ[Hb] and Δ[HbO₂] for all subjects (Fig. 5). Highly significant negative correlations were observed for both time series (p<0.0001 for all the subjects) and averaged elevations.

Table 1. Correlation between Δ[Hb] and Δ[HbO₂] time series

| Subject ID | p value | R value |
|------------|---------|---------|
| 1          | <0.0001 | −0.888  |
| 2          | <0.0001 | −0.985  |
| 3          | <0.0001 | −0.957  |
| 4          | <0.0001 | −0.958  |
| 5          | <0.0001 | −0.978  |
| 6          | <0.0001 | −0.978  |
| 7          | <0.0001 | −0.976  |
| 8          | <0.0001 | −0.885  |
| 9          | <0.0001 | −0.992  |
| 10         | <0.0001 | −0.979  |
| 11         | <0.0001 | −0.962  |
| 12         | <0.0001 | −0.999  |
| Averaged   | <0.0001 | −0.981  |
4. Discussion and conclusion

Based on our previous study on cupping therapy, we explored the mechanism of cupping therapy on the acupoint of kidney in this study. The inspected area is close to spinous process of second lumbar vertebra and is often applied during cupping and/or acupuncture therapy for low back pain. The results imply that cupping therapy provides a therapeutic effect by recruiting the blood from the surrounding area to the treatment area.

During the cupping stage and post-cupping stage, the \([\Delta[Hb]]\) changes significantly reflected a physiological event that blood was transferred from other areas into the treatment area promptly due to the lower air pressure, then the blood flew out from the treatment after the restoration of air pressure. Cupping therapy also influenced the oxygen level of tissue and cased redistribution of blood oxygen. The \([\Delta[Hb]]\) were mainly contributed by the \([Hb]\) and more \([Hb]\) flew into the cupping site during the treatment. In the theory of TCM, cupping therapy can excrete Xieqi (something like harmful substances) from our body. Most of the harmful substances which are mainly produced by metabolism are contained in the venous blood. Therefore, the \([Hb]\) carried the harmful substances into the cupping site. The telltale sign (mostly in dark red color) appeared after cupping treatment also reflected that the metabolic wastes from neighbor tissue gathered around the cupping site. A study of TCM also suggested that the negative air pressure lower than \(-0.03\) MPa can promote the excretion of metabolic waste and accelerate metabolism in the body [5]. The perfect negative correlation between \([\Delta[Hb]]\) and \([\Delta[HbO_2]]\) suggested that the low air pressure block the blood flow from surrounding are into the cupping site. The consumption of oxygen caused \([HbO_2]\) converting to \([Hb]\). Combining the results of our former study [13], the \([HbO_2]\) was blocked in the surrounding tissue, suggesting that cupping therapy help the surrounding tissues to obtain more oxy-hemoglobin. Therefore, the surrounding tissues with enriched oxygen can rebuilt themselves and recovered from painful faster [18]. For the cupping site, the capillaries were minor injured by low air pressure, which is helpful for the tissues to activate self-repair and accelerate the new superseding the old according to the TCM theory. Besides, the NIRS signals from 1.5cm depth of tissue indicated the changes of hemodynamic parameters in skeletal muscle. Therefore, cupping therapy can regulate the blood oxygen and metabolism of skeletal muscle to relieve muscles ache.

The correlations between cupping stage and post cupping stage for hemodynamic parameters indicate that the sustaining hemodynamic alterations were highly relevant to the cupping therapy and may be reasonably considered as a residual effect of the treatment.

We found individual difference in change values. The main reason may be the different weight and body fat percentage among subjects. The fat layer contains fewer blood vessels than muscle. Besides, weight and body fat percentage also produce an effect on the elasticity among subjects, which cause the cup sucked variety volume of tissue. We will take these two
parameters into account and explore the relationship between weight/body fat percentage and hemodynamic change values in our future study.

Compared to our previous study locating the NIRS probe surrounding the cupping site [13], this study embedding the probe on the cupping site make a complementation. Results and trends of $\Delta [\text{HbO}_2]$, $\Delta [\text{Hb}]$ and $\Delta [\text{tHb}]$ in this study are just the opposite to our previous one in both cupping stage and post-cupping stage. Combining these two studies, we can get a relatively complete picture of the cupping therapeutic effect that recruit blood volume and redistribute oxygen level in cupping site and neighbor tissues.

In conclusion, we used CW-NIRS to assess the hemodynamic changes during cupping therapy over 13 subjects. Results showed that the cupping therapy help to gather harmful metabolites from neighbor tissues by [Hb] and excrete them from the cupping site.

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**Disclosures**

The authors declare that there are no conflicts of interest related to this article.

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