Fuzzy C-means Clustering Analysis to Monitor Tissue Perfusion with Near Infrared Imaging

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Abstract. During surgery, conventional or minimally invasive, a surgeon's ability to identify biological tissue properties is critical. Near Infrared (NIR) Imaging, a continuous, non-invasive imaging modality, offers a surgeon an augmented perception of the tissue characteristics (oxygenation, edema, etc.) In this paper, we present our NIR imaging setup and cluster analysis for localizing areas of similar NIR light absorbance, which relates directly to the tissue's Hb, HbO_2, and H_2O content. Through NIR imaging, a surgeon is equipped with auxiliary information to determine the extent and location of tissue injury.

1. Introduction

The ability of a surgeon to perceive the physiological state of biological tissue within the surgical field is paramount. Methods such as x-ray angiography and functional MRI give a surgeon vision into patient's physiology, but there are tradeoffs between functionality and hindrances, such as invasiveness and real-time functionality. Near Infrared (NIR) light has already been harnessed within the operating rooms as it is an 'optical window' [1] into the body. Several publications on NIR spectroscopy have been written detailing how NIR spectroscopy can be used to monitor physiological information [1, 2]. Spectrophotometry, however, is only a point measurement. NIR imaging, on the contrary, can give a surgeon both physiological and spatial information about the surgical field; it will give information that will aid the surgeon in localizing areas of injured tissue during surgery

In Mansfield's previous work [3] NIR imaging was used to monitor oxygenation and perfusion gradients on the reverse McFarlane skin flap model: a well-publicized model that creates an ischemia gradient across a section of tissue [4]. Fuzzy C-means clustering analysis was used on multi-spectral images to identify regions of adequately and poorly perfused tissue 1hr post surgery. Our work expands upon Mansfield's study by monitoring the tissue properties during perfusion changes.

2. Methods

A. Surgical procedures

The reverse McFarlane skin flap model [4] is ideal for establishing regions of tissue with a graded level of perfusion. For our experiments, we used anesthetized wistar rats (~400 g) with a maintained body temperature of 37ºC. A 3x10 cm long skin flap was raised from the shaved dorsum of the rat and remained attached at the distal end, keeping only the sacral vessels intact for perfusion. Over time, the oxygenation gradient formed from limited perfusion.

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B. Optical Setup and Image Processing

Monochromatic light was used for illumination at different wavelengths (750nm, 800nm, 830nm, 850nm, 925nm). The skin flap was illuminated while five spectral images were captured with a NIR enhanced camera (KPF2, Hitachi Denshi Corp.) in a dark room. All images were preprocessed with median filtering and a logarithmic residual correction method to calibrate the images [3]. Fuzzy C-Means cluster analysis (FCM)[3] was used to identify regions of tissue with similar spectral responses; responses that relate directly to tissue perfusion. The results of the FCM analysis are maps displaying each cluster and each cluster's NIR absorption spectrum.

3. Results and Conclusion

Figure 1a shows an example of a skin flap image with the clustering map superimposed over the visual image (right side is the pedicle and the left side is distal to the pedicle). Figure 1b shows over time the absorption characteristics for the cluster farthest distal from the pedicle. There is an increase in absorbance for the 750 nm, which might reflect the presence of more Hb, while there is a decrease in the absorbance at 925 nm, which might be the absence of H_2O content. Figure 1c shows the absorption characteristics for the cluster most proximal to the pedicle, which shows very little absorption change over time. We believe this is due to the skin flap remaining adequately perfused. We conclude that NIR imaging has the ability to detect changes in tissue properties, both spatially and physiologically, which would be a great boon to a surgery.

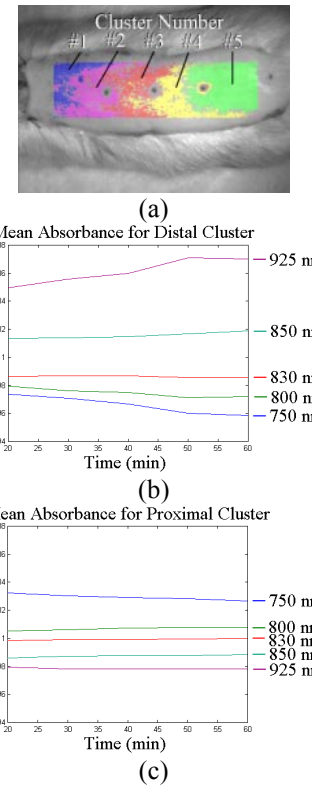

Fig. 1: The clusters from FCM (a) were monitored over time. The most distal cluster (b) shows a decrease in 750 nm reflectance and an increase in 925 nm reflectance over time, while the proximal cluster (c) remains the same. We conclude that the distal cluster has an increase in Hb and a decrease in H_2O, while the proximal cluster remains adequately perfused.

References

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