ISCHEMIA SENSING SURGICAL INSTRUMENTS

JOHNS HOPKINS
MEDICINE
DEPARTMENT OF SURGERY

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Introduction

Surgical techniques rely heavily on adequate visualization of target anatomy. In laparoscopic and robotically assisted laparoscopic surgery, the operative anatomy is removed from the surgeon's direct vision. In addition, the general view of the operative field is often obscure. As a result, peripheral anatomy is out of view. Manipulation of this peripheral anatomy may lead to ischemia, infarction, and mechanical disruption. The primary goal of the technology described is to minimize unnecessary damage to manipulated anatomy through the incorporation of biofeedback sensors into surgical instruments.

Problem Addressed

Retraction injuries are due to the following: prolonged ischemia leading to tissue dysfunction, infarction, or mechanical disruption. Tissue ischemia occurs at a depth proportional to retraction force. Capillary flow is occluded at a pressure of approximately 17 mm Hg. The time at which ischemic damage occurs depends on the metabolic activity of the retracted tissue. Figures 1 & 2 demonstrate a porcine liver after a 46 minute period of retraction with a sustained pressure of 76 mm Hg. This pressure was generated by the retractor shown above. Permanent discoloration of the retracted liver tissue (red arrow) is seen in contrast to normal liver (green arrow).

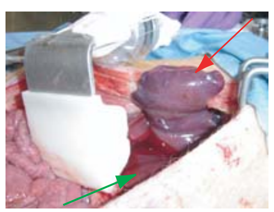


Figure 1

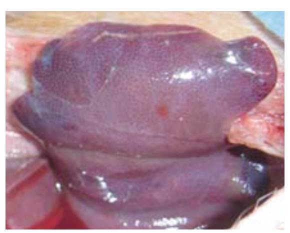
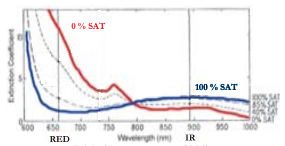


Figure 2

Technology

Pulse oximetry techniques rely on the difference in light absorption properties of oxygenated hemoglobin (HbO_2) and deoxygenated hemoglobin (Hb). The figure shown demonstrates that light absorption increases for Red light and decreases for Infrared (IR) light as the oxygen saturation decreases. The measured relative absorption of Red and IR light transmitted through the tissue gives information about the oxygen saturation level. With high intensity light emitting diodes (LEDs) and sensitive photodiodes, this technology can be extended to measure local tissue oxygen saturation levels to prevent ischemic damage.



Original image courtesy of Nellcor

Algorithm:

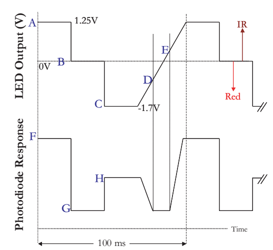
1) Output IR light (A) and monitor response (F)
2) Turn off output (B) and monitor response (G)
3) Output Red light (C) and monitor response (H)
4) Ramp light intensity from Red (C) to Off (B)
   Determine where the response is lost (D)
5) Ramp light intensity from Off (B) to IR (A)
   Determine where the response is regained (E)

Individual ratios for Red and Infrared:

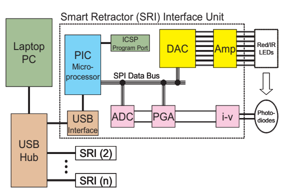
$$\tau_{Red} = \frac{H - G}{|C - D|} \qquad \tau_{IR} = \frac{F - G}{A - E}$$

Relative Oxygen Saturation:

$$R_{O_2} = \frac{\tau_{Red}}{\tau_{IR}}$$



Annotated Timing Diagram



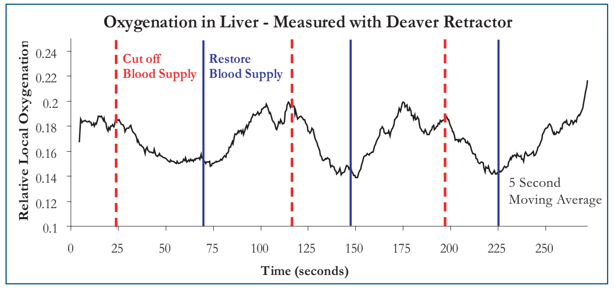
Block Diagram of Retractor Interface

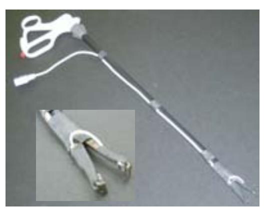
Custom Retractor Interface

Preliminary Results

Deaver retractor with ischemia sensing sleeve and force sensor

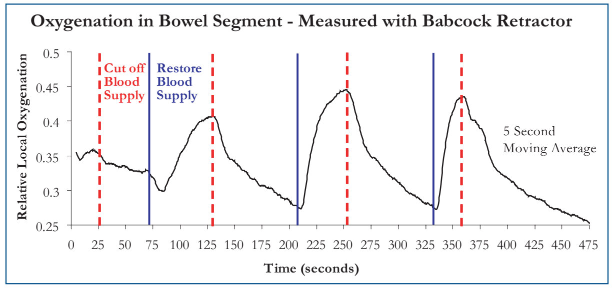
Retraction of liver while manipulating blood supply





Instrumented Babcock retractor (Oxygenation sensors in close-up)

Measuring oxygenation of isolated bowel segment



Future Work

We have created a system in which surgical instruments can detect trends in tissue oxygenation levels. These trends will enable the surgical team to minimize instrument induced tissue damage. Future endeavors aim to explore the following issues: (1) correlation of tissue specific ischemic time to permanent damage; (2) correlation of retraction forces to critical ischemic damage and / or mechanical disruption; (3) development of a system which utilizes metrics to alert the operative team of impending damage; (4) development of a training and assessment tool for surgical assistants; and (5) incorporation of the system into robotically controlled surgical platforms in order to enhance the human - machine interface.

Acknowledgements

The authors would like to acknowledge the assistance of the Johns Hopkins Minimally Invasive Surgery Training Center (MISTC) and Randy Brown, DVM, Sue Eller, RVT, Alexander Aurora, MD, and Joshua Felsher, MD for their assistance and guidance. Partial funding for this project was provided by NSF Engineering Research Center Grant #EEC-97-31478 and Johns Hopkins internal funds.

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