NeuroTiC: Optical Strain Analysis of Brain Tissue

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Introduction

Tissue compliance is a measure of the stiffness of a tissue which can be related to the perfusion of blood—or pulsatility—through said tissue. This parameter can be used to gauge patient health while under anesthesia during open brain surgeries, or craniotomies. Surgeons currently measure brain tissue pulsatility by pressing a finger on the brain; it is a qualitative assessment rather than a quantitative one. Accordingly, the surgeons make educated guesses as to brain tissue health during surgery. There is no device or system on the market which can empirically evaluate pulsatility in real-time without direct contact with brain tissue. NeuroTiC is a system which optically tracks surface displacement and combined with pressure measurements outputs pulsatility data. A proof of concept was constructed to demonstrate the tracking of displacement. NeuroTiC has the potential to provide quantitative data to surgeons regarding brain tissue health, improving surgical outcomes from craniotomies.

Materials and Methods

NeuroTiC's hardware component simply requires a quality camera which can take accurate, detailed pictures of the operation. The software component utilizes a digital image correlation (DIC) software; the DIC software used by NeuroTiC, Ncorr[1], tracks displacement between pictures taken by the camera. For a proof of concept, a marked balloon and plastic skull were used to simulate a craniotomy. The skull had an upper portion removed, approximately 12 cm wide. The balloon was inflated inside the skull with 700 mL of water. A reference image was taken. Afterwards, balloon was inflated with a volume of 720 and 730 mL of water across two separate trials; these were used to gauge the efficacy of NeuroTiC's displacement tracking. In this proof-of-concept, displacement alone was calculated; pulsatility requires pressure measurements, which would be present in an operating room but were not applicable for this proof-of-concept. Surface displacement can be used to calculate volumetric strain, which combined with pressure, outputs pulsatility (change in pressure over change in volume).

Results and Discussion

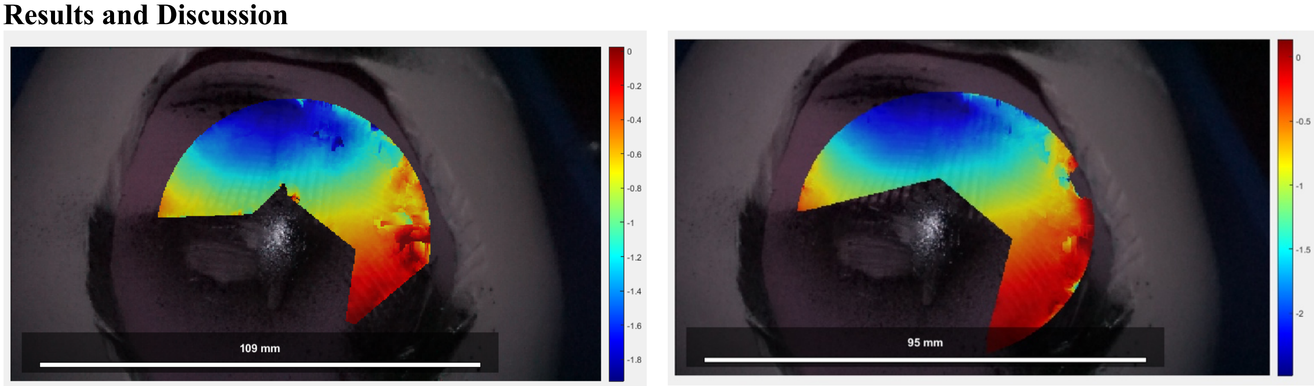

Figure 1: Displacement results, in millimeters, of the Y-Axis for tests 1-4 (left, 20mL expansion) and 1-5 (right, 30mL expansion). The legend to the left clearly demonstrates that the larger expansion results in larger displacement.

Shown in Figure 1 are the Y-Axis displacement results from NeuroTiC. On the left is the output of test 1-4, where the balloon was inflated by an additional 20 mL. The red portion, closer to the equator of the balloon, shows almost zero vertical displacement. This is because the balloon here is expanding towards the camera, on the Z-axis; that displacement is not calculated here. However, closer to the edge of the balloon, in the blue region, the maximum displacement increases to 1.8mm, as the balloon expanding makes that region expanding upwards rather than forwards. Similarly, the right image of test 1-5 shows a similar pattern; here the maximum displacement is about 2.4mm, as the volume increase is larger (30 vs 20mL). Clearly, NeuroTiC can be used to quantitatively measure displacement on the surface of a balloon, which is the most difficult part of NeuroTiC's data collection. The other portion (pressure change) would be monitored during surgery and provided during use.

Conclusion

NeuroTiC can provide empirical data of surface displacements during balloon expansion and can provide quantitative data showing that a larger volumetric increase results in larger surface displacement. Further work will incorporate strain gauges to refine the accuracy of NeuroTiC's results and its mathematical model.

References:

[1]Blaber, J., B., *Exp. Mech.* (2015) 55: 1105-1122.