Quantifying Force in Robotic Surgical Systems: The First Step Towards Haptics

Olivia Fukui MD[1], Scotty Chung[2], Kristina Fioretti MD[1], Mulham Soudan[2], Emma Coltoff2, Maggie Bosley MD[1], Carl Westcott MD[1], Philip Brown PhD[2],
[1]Atrium Health Wake Forest Baptist, [2]Wake Forest University School of Biomedical Engineering and Sciences

Introduction

Surgical robotic systems currently have no force feedback or haptic interface with the user. This is seen as a major detractor to robotic surgery as well as an area for research and improvement. The first hurdle to haptics is measuring force on the robotic arms and instrument tips. Quantifying these forces could lead to optical or physical force feedback to the operator. Ventral hernias are a unique challenge and good experimental model due to complex loading of the abdominal muscles with primary closure. We sought to understand how application of forces during ventral hernia repair could improve the handling of suture and tissue leading to improved accuracy and outcomes.

Methods and Procedures

WFU biomedical engineering acquired a first generation DaVinci robotic system and utilized the DaVinci Research kit (dVRK) framework for research. A custom Mega Needle Driver tool was slotted and fitted with optical fiber strain gauge to enable force estimate occurring at the tip and along the instrument shaft. A cadaver without prior abdominal surgery was used. An elliptical hernia defect was created in the anterior abdominal wall musculature and the skin closed over it. The fascial defect was closed primarily using a 2-0 Stratafix. A second hernia was created by excising an additional 1cm around the previous defect. The same ports were utilized for the second repair. A peak detection model was utilized to determine when forces above 10N were applied. The peak force values and number of occurrences were compared between the two hernias.

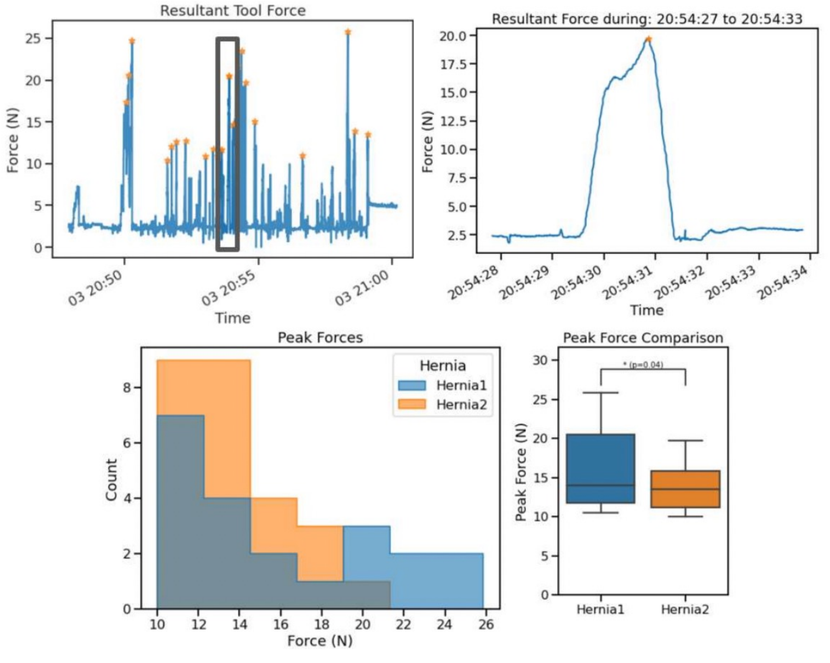


Figure 1: (Top-Left) Forces throughout the entire first hernia procedure. A small segment centered around a peak is shown in the Top-Right. (Bottom-Left) A comparison of the peak forces between the first and second hernia. (Bottom-Right) A boxplot showing the distribution of peak forces during each hernia.

Results

The max and average peak forces applied per hernia are shown in Figure 1 along with the measured defect size. In Figure 1 we show the force versus time graph for the hernia procedure and a small interval centered around a detected peak. This also shows a comparison of the peak forces between the two hernias. A t-test comparing the peak forces between the two repairs found a significant difference ($p<0.04$).

Conclusions

We have demonstrated a system to capture force readings during robotic surgery. Despite the second hernia being larger, a lower peak force was applied during the repair. However, there were more occurrences of high force loads. A significant difference between the two hernias is not surprising due to the hernia size and a different surgeon performing the closure. While several improvements to technical issues of this system are required, the concept of force measurement is demonstrated and proven feasible.