Guiding Robotic Surgery with 3D Ultrasound: A Study of Instrument Size on Surgical Performance

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1 Introduction

Real-time 3D ultrasound (US) has become a promising new tool for guiding surgical procedures [1]. In particular, minimally invasive applications within a beating heart are now possible because of US's high tissue/blood contrast and a temporal resolution capable of capturing fast-moving cardiac structures [2]. Intra-cardiac beating heart procedures present new challenges such as limited workspace and a highly dynamic environment. A surgical robot's abilities are well suited for these conditions, due to increased dexterity, accuracy, and speed. However, the use of US to guide surgical procedures decreases a surgeon's ability to perceive and manipulate surgical instruments, as US is not well suited for imaging hard highly reflective objects. We are beginning to explore these new challenges and numerous ways to overcome these shortcomings. In this paper we evaluate the performance of subjects controlling a surgical robot and using real-time 3DUS for guidance. Specifically we looked at the role of instrument size and how it affects a subject's ability to control a surgical robot.

2 Methods and Materials

We evaluated subjects controlling a surgical robot with 3DUS used for guidance. The surgical robot used in this study was a Laprotek 6 degree of freedom surgical robot. Subjects controlled two surgical graspers from a master console while watching a monitor displaying images acquired with a real-time 3D US system (Live 3D Echo, Philips Medical Systems). Six subjects participated in the study, all between 24-32 years old and with limited experience with a surgical robot. After a short practice session, subjects performed two tasks: (1) pick up a vertically positioned rod and (2) pass the rod from one grasper to the other. The rods consisted of 5 stainless steel hypodermic tubes of varying size (0.02 - 0.05in diameter). Both tasks were performed 5 times for each rod size, resulting in 25 trials per subject.

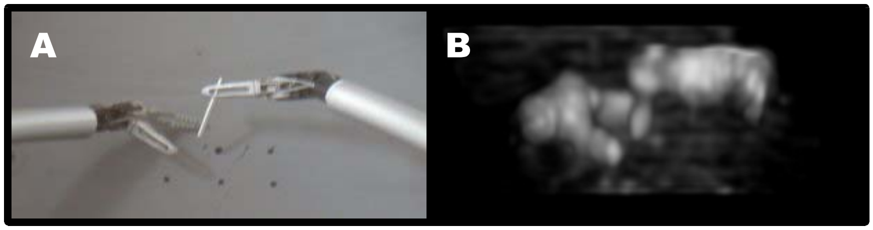

Figure 1: (A) Image of passing object from one grasper to the other. (B) Corresponding 3D ultrasound image.

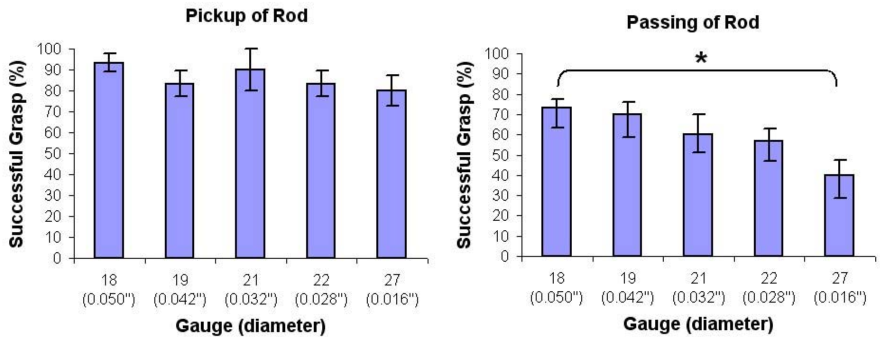

Figure 2: Percentage of successful grasps when picking up and passing a hypodermic tube. Bars are standard error and stars denote significant difference for paired t-tests ($p \leq 0.05$)

3 Results

Subjects successfully picked up objects, regardless of diameter, between 80-90% of the time (Figure 2). However, passing the instrument from one grasper to the other proved increasingly difficult as the object's diameter decreased. Subjects were able pass the object 30% less often with the smallest object than the largest. This is largely due to the higher complexity of the task of passing an object from one grasper to the other. Little visual information is needed to pickup a stationary object as subjects easily compensated for missing or obscured visual information. With increased task complexity and the dynamic nature of the task, object size becomes significant. Future work is under way to explore the effects of surface properties in addition to size, i.e. coatings and surface finishes and how they affect the ability to guide a surgical robot with 3D ultrasound.

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References

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