Ergonomic review of the factors resulting in localised fatigue with surgical robotics

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Ergonomic reviews of surgery in specialist field, such as laparoscopy where equipment has been developed to increase the dexterity and manipulability of tools during surgery, are becoming more popular (Lawson et al., 2007). There have been few similar review of ergonomic issues associated with CAOS (Computer Aided Orthopaedic Surgery ) UKA (Unicompartmental Knee Arthroplasty) procedures, especially relating to the development of robotic surgical systems. As first generation device these systems have mainly focused on the accuracy of the milling process without necessarily completing a user centred design process.

There is an increasing prevalence of haptic devices in many engineering fields, especially in medicine and specifically in surgery (Okamura, 2009). The stereotactic haptic boundaries used in CAOS UKA systems for assistive milling control can lead to an increase in the force required to manipulate the device; this study presented here has seen a several fold increase in peak forces between haptic and non-haptic conditions of a semi-active preoperative image system.

Orthopaedic Arthroplasty surgeons are required to apply forces ranging from large gripping forces to small forces for delicate manipulation of tools and through a large range of postures. There is also a need for surgeons to move around and position themselves to gain line of sight with the object of interest and to operate while wearing additional clothing such as the protective headwear and double gloves (Shih et al., 2001). These factors further complicate comparison with other ergonomic studies of robotic-user interfaces. While robotics has been implemented to reduce fatigue in surgery one area of concern in CAOS is localised user muscle fatigue in high volume use.

“In the context of ergonomics and work physiology, muscle fatigue is defined as any exercise-induced reduction in the maximal capacity to generate force or power” (Lin et al., 2004). “This leads to a reduction in the surgeon’s fine motor control and, hence, a reduced precision of the surgeon’s hand movement.” (Slack et al., 2008)

Fatigue is a very subjective term and is defined here through localised muscle fatigue and its associated discomfort as an indicator. While there are a number of clinical measures of fatigue these are not specific enough for the targeted research that was being carried out and hence a discomfort scale was used in combination with EMG to further indicate the muscle groups that were fatiguing and provide a validation for an associated Biomechanical model.

In order to create the conditions necessary for the generation of fatigue in a realistic user experience, but in the time available for the participants, an extended period of controlled and prolonged cutting and manipulation of the robotic arm was needed. This pragmatic test requirement makes the test conditions slightly artificial but does indicate areas of high potential for fatigue when interacting with the system in high volume instances.

The surgeon-robotic system interaction was captured using 3D motion analysis and a force transducer embedded in the end effector of the robotic arm and modelled using an existing upper body model in “Anybody” software. The kinematic and force information allowed initial calculations of the interaction between the user and the RIO system. Validation of the model was conducted using EMG assessment of activity and fatigue. Optimisation of the model sought to create an efficient cutting regime to reduce
cutting time with reduced muscle force in an attempt to reduce users discomfort/fatigue while taking into account anthropometric variations in the users and minimising overall energy requirements, burr path length and maximum muscle force.

From the assessment of a small group of three surgeons with experience of the RIO system there was little to no experience of above normal localised fatigue during small volume use of the system. Observation of these surgeons operating the robot state otherwise with examples of reactions to discomfort. There is also anecdotal evidence that fatigue becomes more problematic in higher volume work loads.

References