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„Effects of Force-Feedback in Robotic Heart Surgery: Dependency on the Level of Surgical Skill"

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Effects of Force-Feedback in Robotic Heart Surgery: Dependency on the Level of Surgical Skill

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INTRODUCTION

Currently available robotic surgical systems do not provide haptic or tactile feedback. The lack of haptic (force or tactile) feedback causes damage of tissue and bending or breaking of suture material [MacFarlane1999]. For further improvement of telemanipulated systems [Bholat1999] haptic was implemented into an experimental platform (fig. 1) and force-feedback was evaluated for robotic heart surgery.

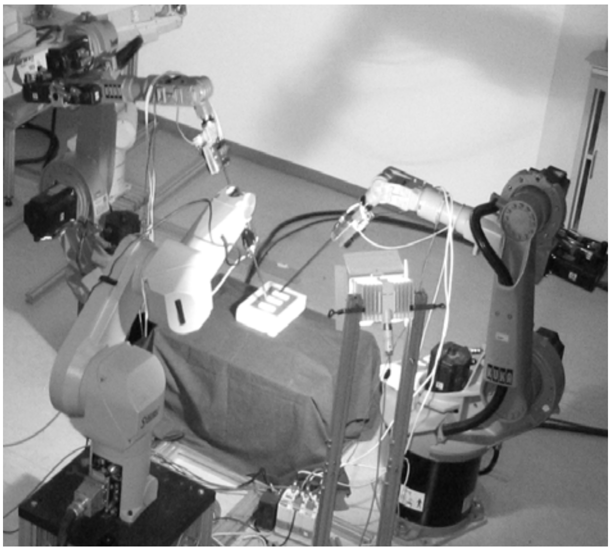

Fig. 1: Experimental robotic platform with integrated haptic feedback

The hypothesis, that haptic feedback in form of sensory substitution facilitates the performance of surgical tasks [Falk2003], is evaluated with special respect to the surgical skill.

MATERIALS AND METHODS

The human subjects of this study included 25 heart surgeons in different levels of surgical training and age. Three groups were defined: One group of 8 with young surgeons, the second group with 12 experienced surgeons and the third group of 5 with roboter-trained surgeons.

The study intended basic surgical and cardiac surgical procedures. Knot tying, breaking of suture material (the rate for telepresence of the system) and palpating arteriosclerosis (fig. 2) had to be performed in a defined cycle with double blinding.

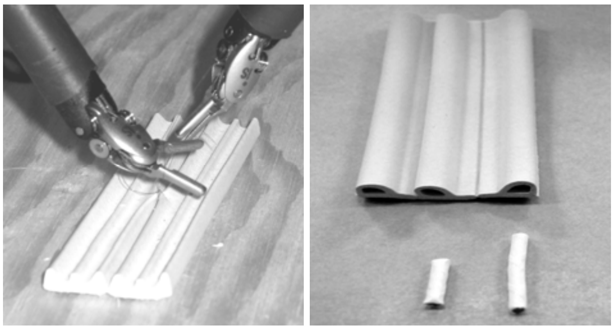

Fig. 2: Evaluated surgical procedures: knot tying and palpating vascular stenosis

The participants dealt with three levels of haptic feedback: no haptic, actually fed back forces (1:1) and enhanced force-feedback (1:2).

RESULTS

The experience of the surgeons does not influence the amount of applied forces (p>0,05). Haptic feedback does not show any influence on the quality of surgical knot tying (p=0,05, fig. 3).

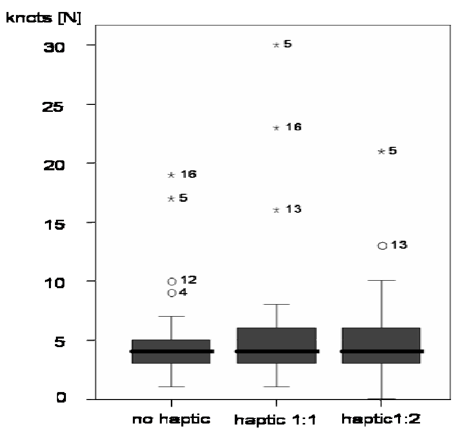

Fig. 3: Amount of knots with haptic feedback (p=0,05)

The visual fatigue decreases while operating with force-feedback for young, conventionally and robotic experienced surgeons. Haptic feedback decreases the visual stress and fatigue ($p<0,05$, fig. 4).

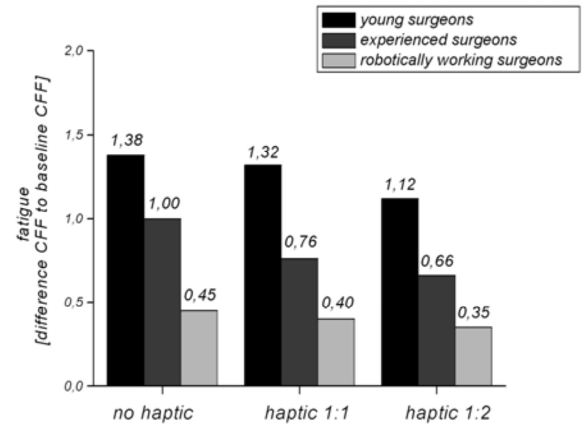

Fig. 4: Decreased visual fatigue with haptic feedback.

Roboter-trained surgeons performed faster and showed less initial fatigue and a tendency to reduced fatigue with haptic feedback.

DISCUSSION

Haptic feedback is currently limited to interact with rigid structures, such as tool-on-tool collisions, not soft tissues. This requires the surgeon to rely on visual feedback in tasks such as suturing. The basic consideration is to offer the heart surgeon an accessory sensory channel in addition to the visual channel not only to avoid breakage of surgical suture material and tissue, but also to decrease visual fatigue.

The applied forces decrease significantly with force feedback, but we could not find significantly less tissue trauma. This is likely due to the fact, that artificial tissue and arteries even close to real tissue do not represent the genuine violability and the bleeding component of natural tissue.

The new system feeds back force in two directions. It is quite possible that force feedback applied in three directions (x, y and z) would intensify the perception of haptic feedback. The question is the necessity of three fed back dimensions in surgical tasks. One time consuming procedure during robotic operations is the knot tying. Fact is, an experienced surgeon performs more knots per time unit in conventional surgery than in robotic surgery. This might be due to the fact, that the range motion of the input devices is obviously inferior to the human hand. The number of knots did not increase within the experimental platform with haptic feedback as expected.

Haptic feedback resulted only in a tendency to decrease the visual stress. The working time at the system might be too short for the surgeons to distinguish significant effects.

Potential harmful mistakes can be averted for patient's safety. A heavy collision of instruments in the patient's thorax and with anatomical structures can be avoided by the working surgeon. Furthermore, the immersion and telepresence was higher and enhanced with haptic feedback. There are clear differences in the effect of force-feedback depending on the level of surgical skill.

Robotically-trained surgeons obviously are able to compensate the lack of force-feedback by visual control.

CONCLUSIONS

The goal of these experiments was to examine claims about necessity of force feedback for robot-assisted surgical procedures in cardiac surgery. Haptic feedback is needed for surgical tasks since less force is applied by the surgeon. The experiments showed that haptic feedback can be employed to prevent the surgeon from potentially harmful mistakes like breaking of suture material and consequently losing of the surgical needle. The fatigue of surgeons is decreasing and the perception of telepresence by the surgeons is increasing. The safety for patients operated with a telemanipulator with integrated haptic could be increased.

Future surgical systems with integrated haptic feedback could be used to train young surgeons for exercising and teaching critical and difficult steps of surgical operations by the system as simulator.

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