Implementation of Force Feedback into Telemanipulated Surgery: Assessment of Surgical Experience

R Bauernschmitt[1], EU Braun[1], A Knoll[2], H Mayer[2],
I Nagy[2], R Lange[1]

[1]German Heart Center Munich, Clinic for Cardiovascular Surgery, Munich, Germany
[2]Robotics and Embedded Systems, Technische Universität München, Munich, Germany

Abstract

The evaluation of the haptic feature for surgical tasks especially including the value of surgical experience for telemanipulation is presented. In an experimental telemanipulating surgical platform the amount of force in the dominant and non-dominant hand and its dependency on the surgical experience was examined.

1. Introduction

The introduction of master/slave systems for minimally invasive and endoscopic operations showed shortly after the first series of operations the limitations and difficulties of the system. For further improvement and easier handling of the telemanipulator [1], the feedback of force on surgical skills is evaluated dependent on different surgical experience. The value of surgical experience for telemanipulation is presented including force feedback. Furthermore the surgeon's fatigue arising during operation is investigated in special examinations.

The amount of force in the dominant and non-dominant hand, its dependency on the surgical experience and necessity for consequences in the design of surgical telemanipulators was not yet under examination in previous studies.

2. Methods

Haptic feedback was integrated in an experimental platform based on two robotic manipulators and one endoscopic 3D camera controlled by two input devices [2]. Similar to other systems for robotic surgery, our set-up comprises an operator-side master console for in-output and a patient-side robotic manipulator that directly interacts with the operating environment. The system consists of two surgical manipulators, which are controlled by two input devices (figure 1).

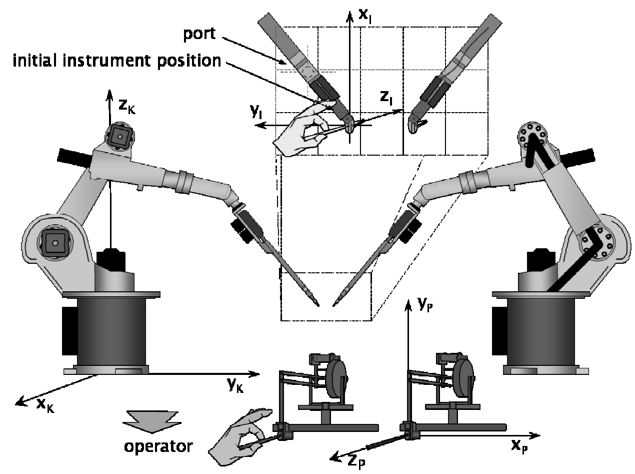

Figure 1. Telemanipulated surgical system.

Each manipulator is composed of a KUKA KR 6/2 robot that bears a surgical instrument of Intuitive Surgical®. Furthermore we developed an adapter to link the robotic arm with the instrument (figure 2).

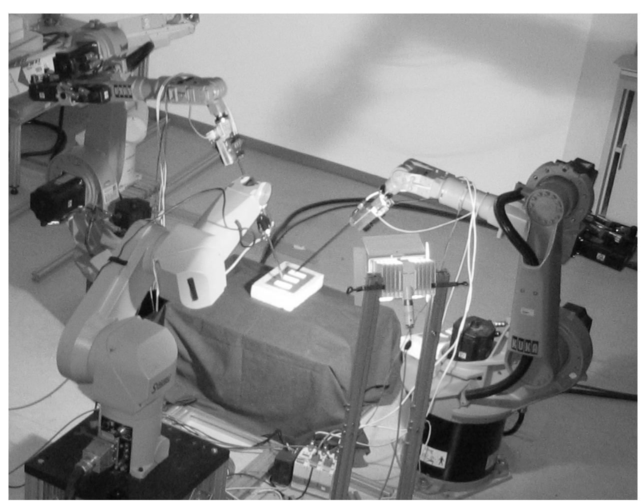

Figure 2. Experimental platform with integrated haptic.

Since the shaft of the surgical instrument is made of carbon fibre, force sensors have to be very sensitive and reliable. Therefore strain gauge sensors are applied, which are employed for industrial force registration. The sensor gauges are applied at the distal end of the instrument's shaft near the gripper. One full bridge of sensors is used for each direction.

The human subjects included 25 heart surgeons divided in different levels of surgical training and age. The human subjects had to tie surgical knots with two surgical instruments equipped with haptic feedback. The surgeons had ten minutes to perform precisely as much knots in alternate way (left and right taught knots) as possible. The applied forces, the breakage of suture material and the speed of motion during knot tying were recorded.

The critical flicker fusion frequency (CFF) is an individual part of the Wiener Testsystem (Schuhfried GmbH, Austria) analysing the progression of fatigue during the evaluation [3]. The CFF is regarded as an indicator for the central-nervous function capacity, the activation level and the progression of fatigue during practical tasks [4].

The CFF is defined as median of the flicker and the fusion frequency presenting a flickering red light five times in ascending and descending intensity. The course of fatigue during the experiment was measured in between three blocks of tasks.

3. Results

While knot tying without force feedback the surgeons were working with significantly different force with the non-dominant hand depending on the surgical experience ($p<0,05$). The experienced surgeons were working with significantly less force in the non-dominant hand than young surgeons ($p<0,05$, figure 3).

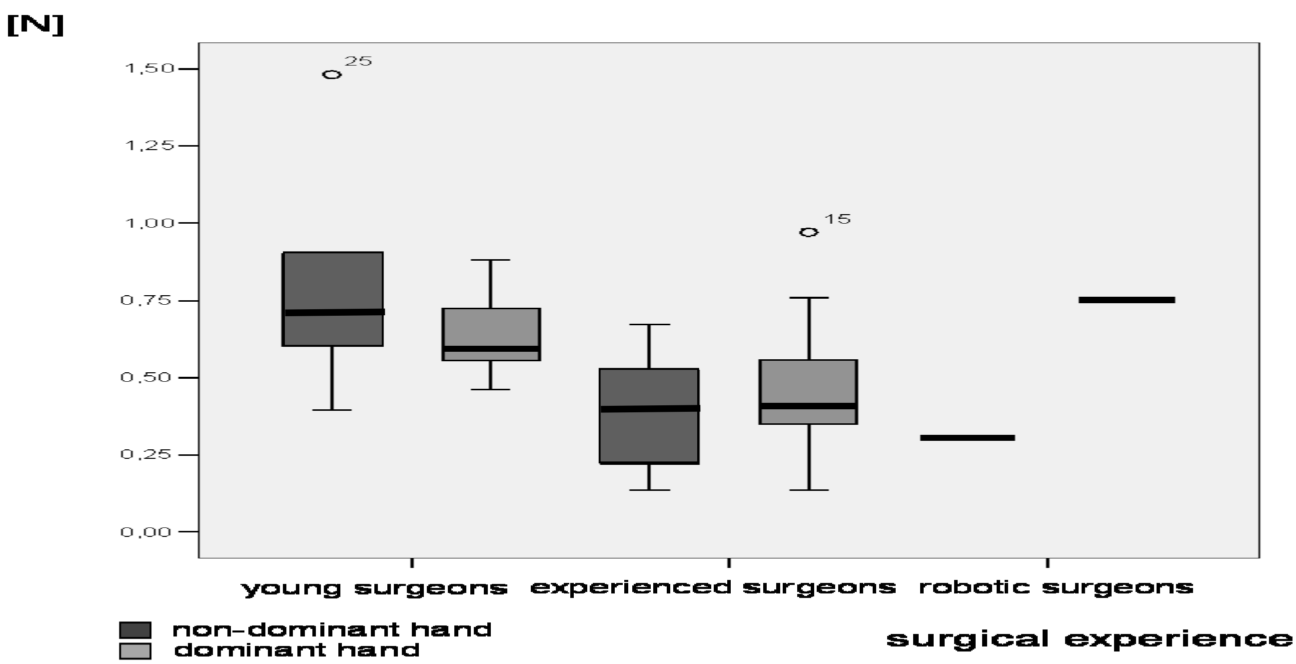

Figure 3. Mean forces of the dominant and non-dominant hand grouped in surgical experience with no force feedback.

With doubled force feedback the surgeons worked in the non-dominant hand with significantly different force dependent on the surgical experience ($p<0,05$). The experienced surgeons worked with significantly less force in the non-dominant hand than the young surgeons ($p<0,05$, figure 4).

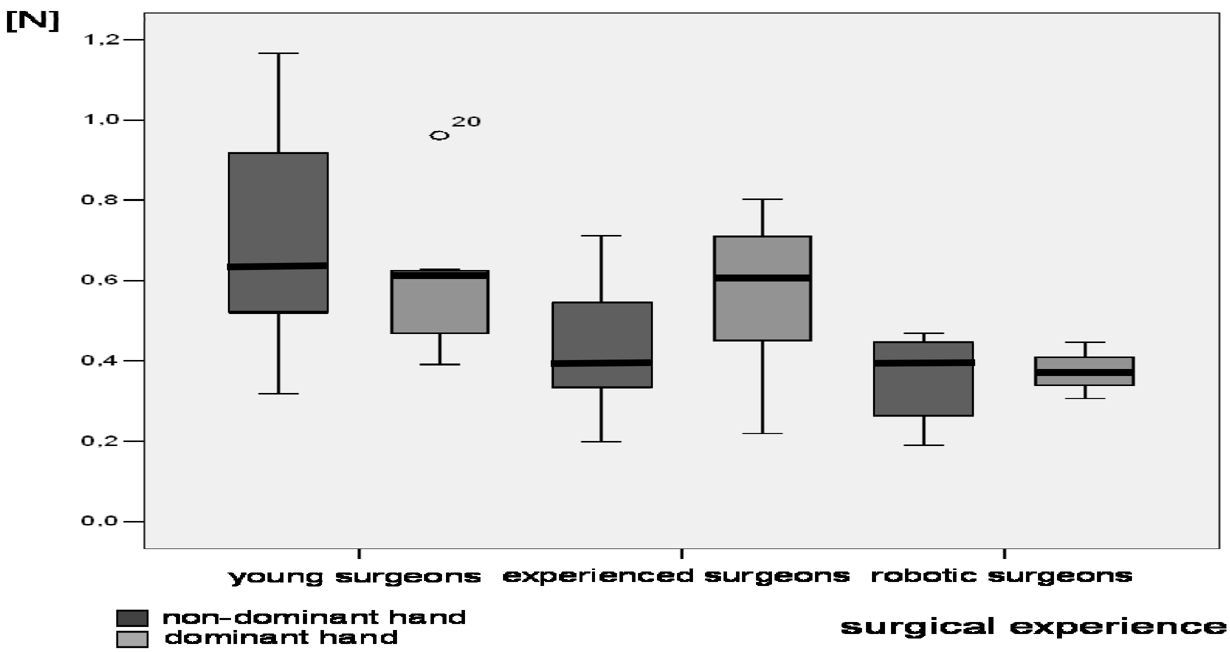

Figure 4. Mean forces of the dominant and non-dominant hand grouped in surgical experience with 1:2 force feedback.

The visual fatigue decreases while operating with haptic feedback. Haptic feedback decreases the visual stress and fatigue especially in robotic experienced surgeons (p<0,05, figure 3).

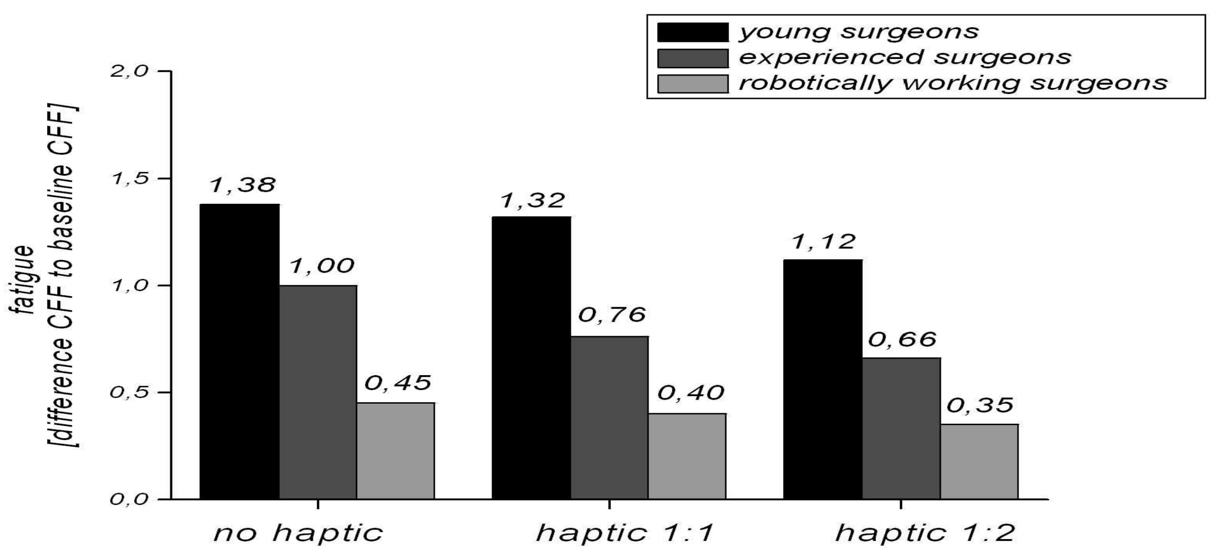

Figure 3. The visual fatigue decreases while operating with haptic feedback.

4. Discussion and conclusions

Our results showed that surgical and robotic experience is a fundamental precondition for telemanipulated surgery. Obviously surgical and robotic experience may contribute to the development of skills that could be relevant for the performance of telemanipulated surgery. 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.

Further studies are needed to determine if training, computer games or training of the non-dominant hand on virtual reality scenarios can increase the surgical outcome [5], decrease the forces and therewith decrease the visual mental stress and workload.

Acknowledgements

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References

[1] Mitsuishi M, Tomisak S, Yoshidome T et al. (2000) Tele-micro surgery system with intelligent user interface. IEEE International Conference on Robotics and Automation ICRA, San Francisco, California, USA, 2000, pp 1607-1614

[2] Nagy I, Mayer H, Knoll A, Schirmbeck EU, Bauernschmitt R (2004) Endo[PA]R: An Open Evaluation System for Minimally Invasive Robotic Surgery. Proceedings of the IEEE-Conference on Mechatronics & Robotics MECHROB 2004, Aachen, Germany, pp 1464-1467

[3] Wiemeyer J. Flimmerverschmelzungsfrequenz und zentralnervöse Aktivierung. Neurol Rehabil. 2002;8(1):29-34

[4] Johansson A, Sandström M. Sensitivity of the human visual system to amplitude modulated light. Arbetslivsrapport Nr. 2003:4. Arbetslivsinstitutet, National Institute for Working Life 2003. Umeå, Sweden

[5] Scott DJ, Bergen PC, Rege RV et al (2000) Laparoscopic training on bench models: better and more cost effective than operating room experience? J Am Coll Surg. 191(3):272-83

Address for correspondence

PD Dr. med. Robert Bauernschmitt
German Heart Center Munich
Clinic for Cardiovascular Surgery
Lazarettstr. 36
D-80636 München
Germany
bauernschmitt@dhm.mhn.de