7. Workshop Automatisierungstechnische Verfahren für die Medizin vom 19. - 21. Oktober 2007 in München

„Simplification of Minimally Invasive Suturing by Grip Automation“

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Band: Fortschritt-Bericht VDI Reihe 17 Nr. 267 „Automatisierungstechnische Verfahren für die Medizin, 7. Workshop, Tagungsband“
Editors: Ralf Tita, Robert Riener, Martin Buss, Tim C. Lüth
ISBN: 978-3-18-326717-0
Pages: 51-52

Simplification of Minimally Invasive Suturing by Grip Automation

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INTRODUCTION

Beginning in the 1990's, minimally invasive surgical techniques have become increasingly widespread. The small incisions and more subtle preparation possibilities allow for beneficial cosmetic implications, a reduction of traumatization, of postoperative pain and morbidity [4]. However, in visceral surgery, the task of viscerosynthesis, i.e. circular anastomosis of hollow organs, is still hard to perform. The requirement to connect hollow organs (viscerosynthesis) has inspired the design of circular stapling devices, tools which are able to perform the task by one click. Their reach is conventionally limited to the oesophagus or the rectosigmoid. The Endostitch® (Autosuture, US Surgical Corporation, Tyco Healthcare, Mansfield, MA, USA) is a more broadly applicable suturing device which can be used for circular full anastomosis in the regions between oesophagus and rectosigmoid, but its manipulation is circumstantial and time- consuming. A redesign of its grip using automation technology is proposed which is intended to simplify its manipulation and to accelerate its use.

MATERIALS AND METHODS

The Endostitch® is applicable at all possible viscerosynthesis operation sites and enables intracorporeal knotting as well as the placement of a continuous suture of several stitches. Its principal drawback is its unintuitive handling. So, to move towards an all-embracing instrument for viscerosynthesis, the Endostitch® does not have to be changed in its suturing functionality, but in the way it is operated.

The original instrument possesses a scissors- like grip (see Figure 1, left). Two reasons complicate its manipulation. Firstly, the hand has to be tilted to keep the instrument in the line of action. Secondly, the hand has to regrip the instrument, has to long for a lever, and has to tilt the lever each time the needle is exchanged between the forcepes. The solution to the problem stated above with respect to these issues is found in the following measures: Firstly, to enable operation in the line of action, the scissors- like grip is replaced by a pistol grip (see Figure 1, right). The forceps is then opened and closed by the pistol trigger. Secondly, to cancel the recurring and distracting regripping of the instrument, the needle exchange between the forceps has been assigned to the same pistol trigger that closes the forceps. Upon closure of the forceps, the needle exchange is done automatically. The result is an instrument which is held in a hand and is operated by one of its fingers. The forceps is opened and closed mechanically by the user via the pistol trigger.

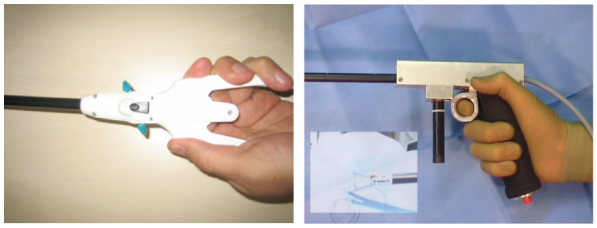

Figure 1 Original (left) and redesigned (right) grip

The pistol grip that has been developed to meet these aims includes a DC motor that decouples the movement which triggers the needle exchange from the actual needle exchange (see Figure 2). Upon closure of the pistol trigger and consequently the forceps, a trigger in the grip activates the DC motor to release the needle from one jaw and to fasten it in the other. Thus, the DC motor assumes the manipulation of the switch in the original instrument (see Figure 1, left).

The opening and closure of the forceps as well as the needle exchange are conducted by three aluminum rods in the instrument shaft. The movement of the medium rod opens and closes the forceps, while the movement of the two exterior rods loosens and fastens the needle. The DC motor is attached to the switch, a wheel that pushes one of the exterior rods into the shaft while retracting the other at the same time. The maximal forces that are required to retract the rods in the shaft of the instrument are 12 Newton (median rod) and 2

Newton (exterior rods). A maxon RE13 DC motor automates the movement of the exterior rods. This motor and its gear are chosen because they result in an optimal tradeoff between size and the maximal force and switching velocity.
The instrument is connected to a PC with Gentoo Linux as operating system. The electronics of the grip are controlled using the realtime application interface RTAI to guarantee stable execution at a sample rate of 1000Hz. Matlab/Simulink/Stateflow is used as rapid prototyping environment to quickly enable improvements of the automation software. The position of the DC motor is controlled by a PD- feedback control designed in Simulink. Stateflow is used to keep track of the state of the instrument and to react on the pistol trigger signal to switch the needle. The software is designed in Simulink and Stateflow and consequently compiled to generate realtime code which is executed on the linux PC using the realtime application interface RTAI.

RESULTS

The mechatronic extension of the Endostitch provides an acceleration and simplification of suturing . The needle can be exchanged up to two times per second between the forceps jaws, faster than any two consecutive stitches would require. The same finger that closes the forceps triggers the needle exchange without the need of regripping. In suturing experiments, about 500 stitches have been done without the grip showing any signs of fatigue- contrary to the needles which had to be replaced about every 200 stitches. The overworked grip simplifies needle mounting: The forceps tongues are closed around the unmounted needle until the pistol trigger is in stop position, and the needle is clamped.

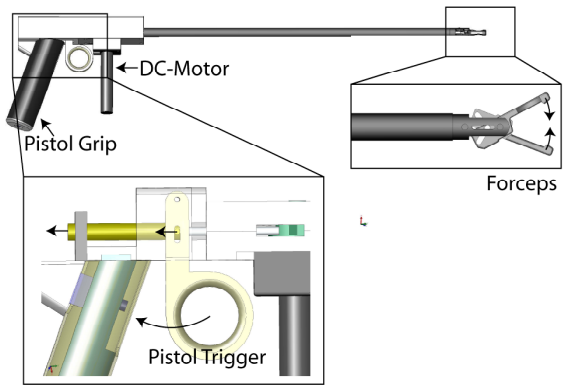

Figure 2 Redesigned grip

DISCUSSION

The grip simplifies the manipulation of the instrument. To be applicable in a operating room, it still has to be redesigned to sustain sterilization.

CONCLUSION

The new grip integrates the benefits of automation while at the same time generating a solution which is suitable to a normally equipped minimally invasive, laparoscopic intervention in visceral surgery, because the degree of automation is moderate.
The instrument will be experimentally evaluated to compare its performance in suturing with that of the original instrument.

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