Towards an Anthropomorphic Design of Minimally Invasive Instrumentation for Soft Tissue Robotic Surgery

Antonia Tzemanaki, Sanja Dogramadzi, Tony Pipe, and Chris Melhuish

Bristol Robotics Laboratory, University of the West of England, Bristol, UK

antonia.tzemanaki@brl.ac.uk, sanja.dogramadzi@uwe.ac.uk

Keywords: minimally invasive surgery, robotic surgery, surgical instrumentation, anthropomorphic design, abdominal surgery

Minimally invasive procedures, such as laparoscopy, have significantly decreased blood loss, postoperative morbidity and length of hospital stay. Robot-assisted Minimally Invasive Surgery (MIS) has offered refined accuracy and more ergonomic instruments for surgeons, further minimizing trauma to the patient [1]. On the other hand, training surgeons in minimally invasive surgical procedures is becoming increasingly long and arduous [2]. In this paper, we outline the rationale of a novel design of instruments for robotic surgery with increased dexterity that will provide more natural manipulation of soft tissues. The proposed system will not only reduce the training time for surgeons but also improve the ergonomics of the procedure.

The weight of the benefits of the most commonly used robotic system, the Da Vinci Surgical System [3], is often questioned due to its great volume and cost. Various multi-moduled continuum surgical robots have been developed; Xu [4] presented a workspace analysis and animation of a 17-DoF robotic effector platform for Single Port Access (SPA) surgery, composed of two snake-like arms and a controllable stereoscopic camera. The SPRINT system [5] is also intended for SPA and comprises two arms, each with 6-DoF. Although both systems have a high degree of dexterity for manipulation of soft tissues, the surgeon will still have to be thoroughly trained to operate these systems, just like the traditional laparoscopic instruments.

The benefits of SPA surgery, besides cosmetic, are not unambiguously proven and accepted by all surgeons due to e.g. higher risk of hernia [6]. Our work starts with the concept of multi-port and hand assisted laparoscopic surgery, where the surgeon can insert a hand through a small incision in the patient’s abdomen, manipulating organs and tissue faster and more efficiently. Our instrument design approach is illustrated with the concept drawing in Figure 1a. Three incisions are needed; one for the camera and two for each of the two hand-like instruments. Each tool carries a three-finger subsystem with 5-DoF articulation of each finger. The surgeon, wearing an adjustable exoskeleton on his/her hands, remotely controls the instruments which imitate the movement of the surgeon’s hands. Two fingers are used as grasping forceps (or Maryland forceps), while the third could be used for extra support and also could be carrying a retracting blade or other knot-tying assisting gripper.

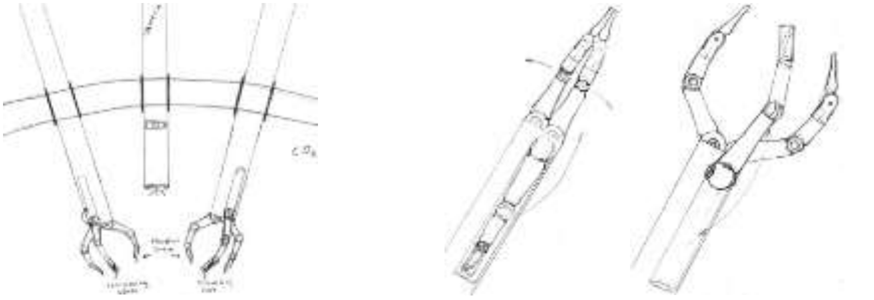

Fig. 1. a. Layout of instruments and camera inside the abdomen **b.** Folded – extended position

The multi-joint structure is foldable and the whole diameter of the instrument is such that the incision is kept to a minimum. The insufflation of the abdomen after the instruments have been inserted allows for safe unfolding into full position, illustrated in Figure 1b. The kinematic and dynamic model was derived and Figure 2 shows the simulation of the system in Matlab. As demonstrated, the thumb is folded back into the arm-structure when the instrument enters the abdominal wall (folded position).

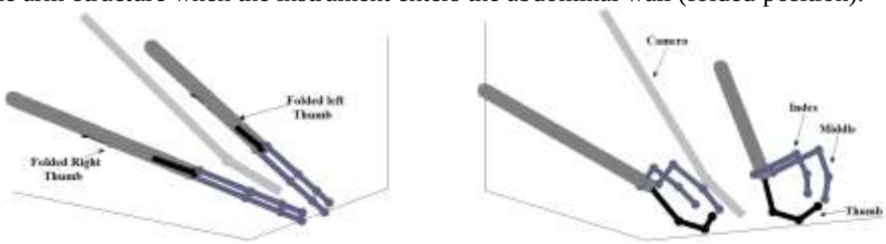

Fig. 2. Simulation in Matlab instruments and camera in a folded and extended position

Although the proposed concept differs from the ones in use at the moment, it is based on the belief that the transition from open to robotic surgery is complex due to the difference in nature of the robotic (as well as laparoscopic) instruments from the surgeon's hands and the open surgery techniques. This assumption is currently being validated through a European survey of minimally invasive surgery practitioners.

Acknowledgements. This project is funded by the Bristol Urological Institute via North Bristol NHS Trust. We thank Mr Raj Persad and Mr David Gillatt for their guidance and cooperation.

References

1. Allemann, P., et al: Robotics may overcome technical limitations of single-trocar surgery, Arch Surg/Vol. 145, No. 3 (2010)
2. A SAGES position paper - Integrating Advanced Laparoscopy into Surgical Residency Training: http://www.sages.org/publication/id/24 (2009)
3. DaVinci Surgical System: www.davincisurgery.com/davinci-surgery (2012)
4. Xu, K., et al.: System Design of an insertable robotic effector platform for single port access (SPA) surgery, IEEE/RSJ International Conference on Intelligent Robots and Systems, 5546-5552 (2009).
5. Piccigallo, M., et al: Design of a Novel Bimanual Robotic System for Single-Port Laparoscopy, IEEE/ASME Transactions on Mechatronics, Vol. 15, No. 6 (2010)
6. Zhang, C., et al: Incidence of incisional hernias increase with single port laparoscopic technique, Sages 2012 Annual Meeting (2012)