Patient Specific Virtual Simulator for the Pre-operative Planning of Robotic Single Incision Laparoscopic Surgery

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The trend of surgical robotics is to follow the evolution of minimally invasive surgery (MIS) which is moving towards single-incision laparoscopic surgery (SILS). SILS has the advantage of entailing one incision and shortening the recovery time. Nonetheless, what seems to offer an advantage of SILS from the aesthetic point of view is an intrinsic limitation of this procedure: in fact having only one single access imposes a coaxial arrangement of the instruments, thus resulting in difficult manoeuvrability due to the proximity of the instrument tips inside the abdominal cavity. The seven degrees of freedom (DOF) for da Vinci® EndoWrist® by Intuitive Surgical (Sunnyvale, United States) could overcome the issue of limited manoeuvrability. However the robotic arms do not work well when arranged coaxially through a single incision due to the risk of possible collisions of the instruments with each other and the camera, leading to a potential instrument malfunction. For this reason new configurations of robot arms are needed to improve surgeons dexterity in single access robotic surgery. Recently, the VeSPA surgical instruments were introduced by Intuitive Surgical specifically to offset many of the limitations encountered with SILS using the da Vinci® while totally new bimanual robots, completely inserted into the patient body, have been proposed in order to enhance the surgeons skills in SILS. These solutions introduce problems related to possible collisions between the anatomies not involved in the intervention and the proximal robot links not directly controlled by the surgeon, who is focused just on the end effectors. To avoid these issues an optimal planning of the positioning of the robot is pivotal.

Despite the success of robotic surgery, developing a surgical simulation system has been a challenge. Simulators based on virtual reality may help novice surgeons to get more confidence with this surgical robotics, thus shortening the learning curve. We present a virtual reality based surgical simulator reproducing the clinical scenario, based on patient specific anatomy, for the correct positioning of a robot with bimanual capabilities. The setup of a surgical robot before performing the actual intervention is of paramount importance due to the limited workspace of the arms. The intent of this simulator is to provide surgeons with a tool for the optimal placement of the access port.

Given a bimanual robot with its own geometry and kinematics, and a patient specific virtual anatomy, the proposed simulator allows to simulate and rehearse the motion of the robot to evaluate if a dexterous movability avoiding potential damages to the surrounding anatomy is feasible. In addition, it is useful to find the optimal positioning of the access port for the robot insertion. In a recent test with five surgeons for the evaluation of the optimal positioning of the access port before a cholecystectomy, the simulator showed promising results in terms of performance and usability.
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