Percutaneous iliosacral screw placement: evaluation of a novel biplanar robot navigation aiming system

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Background: Percutaneous iliosacral screw placement is a standard, stabilization technique for pelvic fractures. It is a demanding operative technique due to the narrow bony corridor and risk of neurological injury. Various methods of guidance are currently available. The medical robot is able to provide a precise and steady mechanical guide to maintain the surgical tool in the right position and orientation during the operation; however, many robotic-navigated systems occupy a large space and their configuration is not adaptable for more functions. The purpose of this study was to assess the effectiveness of a novel biplanar robot navigation aiming system for percutaneous iliosacral screw placement in a human cadaver model.

Methods and Material: The robot body has a compact parallel configuration, which is composed of four linear-motion arms. The arms are designed with a modularization concept to facilitate disinfection and packaging, and one vertical arm and one horizontal arm can define one positioning plane. The screw path is established based on two C-arm images without calibration. The mapping between the coordinate systems is established using a biplanar marker frame embedded with patterned steel balls, and the marker frame is attached to the robot by using a quick connect mechanism. A novel biplanar robot navigation aiming system was used in 16 intact human cadaveric pelvises for percutaneous iliosacral screw insertion. The number of successful screw placements and mean time for this insertion and intra-operative fluoroscopy per screw-pair were recorded respectively to evaluate the procedure. The accuracy of the aiming process was evaluated by computed tomography.

Results: Sixteen intact human cadaveric pelvises were treated with percutaneous bilateral iliosacral S1 screw placement (32 cannulated screws, diameter-7.3mm, Synthes, Switzerland). All screws were placed under fluoroscopy-guided control using the biplanar robot navigation aiming system (TINAV, GD2000, China). There was no failed targeting for screw-pair placements. Computed tomography revealed high accuracy of the insertion process. 32 iliosacral-screws were inserted (mean operation time per screw-pair 56 ± 3 minutes, mean fluoroscopy time per screw-pair 11.7 ± 9 seconds). In post-operative CT-scans the screw position was assessed and graded as follows: I. secure positioning, completely inserted in the cancellous bone (86%); II. secure positioning, but contacting cortical bone structures (9%); III. malplaced positioning, penetrating the cortical bone (5%).

Discussion: The biplanar robot system has the following features that make it suitable for clinical application. No radiation exposure for surgeons is a great advantage. The system is able to calculate the locking path, based on two intraoperative fluoroscopy images from the out-let and in-let views, and to move automatically to the path without further imaging. During X-ray image acquisition, the surgeons can stay away from the radiation region, therefore there is no radiation exposure for the surgeons using the biplanar robot system. Since it basically takes only two intraoperative fluoroscopy images to determine the screw path, the system could significantly reduce the exposure time for patients as well. Compared with other robotic-navigated systems, which occupy a large space and involve complex system configuration, the biplanar robot navigation system has a compact modularized structure occupying less surgical space. During the operation, it is convenient for surgeons to install the robot. Also, the surgeons do not need to change the surgical routines.
Conclusions: This cadaver study indicated that an aiming device–based biplanar robot navigation system is highly reliable and accurate. The promising results suggest that it has the advantages of high positioning accuracy, decreased radiation exposure, operational stability and safety. It can be used not only for the percutaneous iliosacral screw placement but also for other orthopedic surgeries that require precise positioning.

References