CT-3D-fluoroscopy matching navigation of iliosacral screw insertion can reduce malposition rate even for less experienced surgeons

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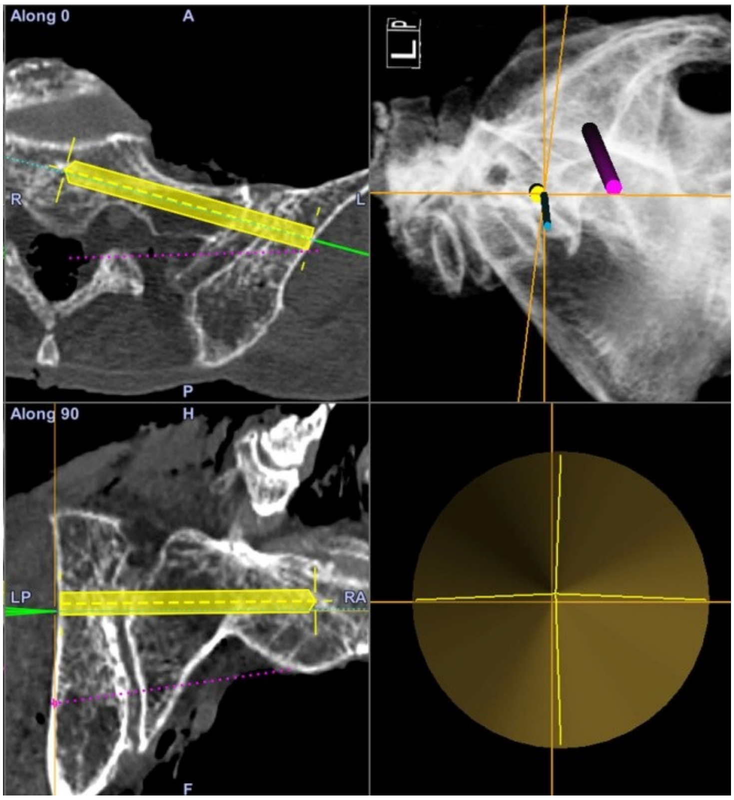
Introduction: Treatment of unstable pelvic ring fractures by transiliosacral screw fixation after accurate reduction has gained general acceptance to rigidly stabilize pelvic fractures and posterior iliosacral ligament ous injuries. Conventional fluoroscopy is the current standard for intraoperative observation. However, Screw malposition rates with fluoroscopic guidance have been reported to range from 2% to 15%, with an incidence of neurologic injury between 0.5% and 7.7% [1]. To achieve proper screw fixation, various authors have used various types computer-assisted techniques including 2D fluoroscopic navigation, computed tomography (CT) -based navigation and 3D fluoroscopic navigation system. Zwingmann reported significantly reduced perforation rate and radiation exposure with 3D fluoroscopic navigation compared to conventional technique, while the perforation rate was as high as 31% in the navigated group [2]. Proper implantation of the screws without perforation of the sacrum or sacral foramina is difficult and requires detailed anatomic knowledge and extensive surgical experience even with use of 3D fluoroscopic navigation. Our null hypothesis that 3D fluoroscopic navigation incorporated with preoperative CT-based plan could enable even less experienced surgeon to perform safe and reliable iliosacral screw insertion. The aims of the present study were to ask whether CT-3D-fluoroscopy matching navigation system could reduce malposition rate in percutaneous iliosacral screw insertion even when performed by less experienced surgeons.

Materials & Methods: This study included 8 pelvises with surrounding soft tissue donated from embalmed cadavers (76–101 years old). The tests were carried out on a Styrofoam board corresponding to an operating table. The board was supported 1 m above the floor with four tripods. Conventional fluoroscopy was performed with a mobile 3D C-arm equipped with a flat-panel detector (Ziehm Vision FD Vario 3D, Ziehm Imaging, Nuremberg, Germany). The navigation procedure was performed using a computer navigation system (Stryker Navigation System II-Cart, Stryker, Kalamazoo, MI, USA) and the mobile flat-panel 3D C-arm. All specimens were scanned with a 64-line, spiral, HR-CT (Aquilion One, Toshiba, Japan) in 1 mm layers before and after surgery The specimens were chosen at random, fixed in the prone position, and draped with loose-fitting, black cloth.

Kirschner wires with a diameter of 3 mm were placed across the bilateral ileum into the S1 and S2 vertebra by four orthopaedic trainee. In 4 specimens, Kischner wires were placed across the right ileum according to a conventional protocol and the left ileum according to a CT 3D-fluoroscopy matching navigated protocol. In 4 specimens, Kischner wires were placed across the right ileum according to a 3D-fluoroscopic navigated protocol and the left ileum according to a CT 3D-fluoroscopy matching navigated protocol. For the conventional protocol, surgery was carried out in a customary manner. Standard lateral, inlet, and outlet fluoroscopic pelvic views were obtained. By rotating these views, a guide wire was placed across the ileum into the S1 and S2 vertebra. Each guide wire was advanced just beyond the sacral midline.

For the 3D-fluoroscopic navigation protocol, a 3D volume had to be created before surgery. First, a reference clamp was placed on the contralateral iliac crest. The target area was fluoroscopically determined in the anterior-posterior and lateral positions, and a collision test of the C-arm was performed. The C-arm was connected to the navigation system and calibrated by registering three points on the detector using a pointing device. Then, 110 single images from a right cylindrical volume of 12 cm diameter and 12 cm height were acquired during a 60-s automated orbital scan of 135°. The DICOM data were transferred from the 3D C-arm to the navigation software. A pointer was used for an accuracy check, and the tools were calibrated. Subsequently, the positions of the screws were planned within the navigation unit. Afterward Kirschner wires were placed into the S1 and S2 vertebra. The wire placement was checked fluoroscopically in the inlet and outlet views. For the CT-3D-fluoroscopic matching navigation protocol, the screw position was planned using the CT data preoperatively.



Procedures until the 3D fluoroscopic image acquisition were the same as the 3D-fluoroscopic navigated protocol. After the data transfer to the navigation, CT-3D fluoroscopy matching was performed by matching intra-operative 3D fluoroscopic images with preoperative CT datasets. First, two sets of images were matched manually. Second, automatic volume registration was performed by maximization of mutual information. Following procedures were the same as the 3D-fluoroscopic navigated protocol. A postoperative CT-based analysis of localization of Kirschner wires was evaluated by one independent surgeon (TM) not involved in the experiment. Perforations were graded according to an established classification method used for correct pedicle screw placement: Grade 0, no perforation; Grade 1, perforation less than 2 mm; Grade 2, perforation between 2 and 4 mm; and Grade 3, perforation greater than 4 mm. The operation duration was timed, starting from the installation of the reference clamp and ending at the final position check, which included the preoperative scan. Moreover, the number of wire insertion until the final position check was counted

Results: We observed a greater percentage of correct screw positions in the CT-3D-fluoroscopy matching navigated group with Grade 0 in 100% compared with correct screw position in the conventional group with Grade 0 in 62.5% (Grade 1, 25%; Grade 3, 12.5%) ($p = 0.006$) and the 3D-fluoroscopic navigation group with Grade 0 in 50% (Grade 1, 12.5%; Grade 2, 12.5%; Grade 3, 25%) ($p = 0.027$). The operation time required per screw was lower in the CT-3D-fluoroscopy matching navigated group (mean; 8 min/screw.) compared to the conventional group (mean; 12 min./screw, $p=0.068$) and the 3D-fluoroscopic navigation group (mean; 13 min./screw, $p=0.068$), while the differences did not reach statistical significance. The number of wire insertion required until the final position check was significantly lower for the CT-3Dfluoroscopic navigation group (1 /screw) compared to the conventional group (4.6/screw, $p=0.027$), and similar to the 3D-fluorosopic navigation (1.4/screw, $p=0.317$).

Conclusion: CT-based 3D fluoroscopy matching navigation system of percutaneous iliosacral screw insertion could reduce malposition rate and number of guidewire insertion even when performed by less experienced surgeons.

References

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