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Accuracy of computer-assisted iliosacral screw placement using a hybrid operating room

P.H. Richter *, F. Gebhard, C. Dehner, A. Scola

Ulm University, Department for Orthopaedic Trauma, Hand and Reconstructive Surgery, Albert-Einstein Allee 23, 89081 Ulm, Germany

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ABSTRACT

Introduction: In recent years hybrid operating rooms were established all over the world. In our setting we combined a 3D flat-panel c-arm (Artis zeego, Siemens) with a navigation system (BrainLab curve, BrainLab). This worldwide unique combination enables the surgeon to visualise an entire pelvis in CT-like image quality with a single 3D-scan. The aim of our study was to investigate, if utilisation of a hybrid operating room increases the accuracy of SI-screws in comparison to standard 3D-navigation.
Material and methods: Retrospective, not randomised single centre case series at a level I trauma centre. Inclusion criterion was insertion of a percutaneous iliosacral screw using image-guidance in the hybrid operating room. 61 patients (35 female, 26 male) were included from June 2012 till October 2014. 65 iliosacral screws were inserted.Intraoperative 3D-scans and postoperative scans were examined to investigate screw placement. The results were compared to a preceding study performed in 2012 using conventional 3D-navigation. Statistical calculations were performed with Microsoft Excel 2011 and SPSS.
Results: 65 iliosacral screws were implanted. Two different types of screws were implanted: 1. "Standard" iliosacral screws stabilizing one joint/a unilateral fracture. 2. Single SI-screws stabilizing both SI-joints and if present a bilateral fracture. Forty one patients were included in group 1 (screws $n = 45$). There was no perforation in 43 screws, grade 1 perforation in 2 screws. There was no grade 2 or 3 perforation in this group. Compared to the conventional 3D-navigated screws there was a highly significant difference ($p < 0.001$). Twenty patients could be included in group 2. Eleven screws showed a complete intraosseous position. There was grade 1 perforation in 2 screws, grade 2 perforation in 5 screws and grade 3 perforation in 2 screws.
Conclusion: Improvements in image quality and enlargement of the display window lead to better intraoperative visualisation of the entire dorsal pelvis. Thereby the accuracy of computer-assisted iliosacral screws could be increased using a hybrid operating room. Furthermore difficult tasks like a single screw for both joints can be accomplished.

Introduction

Isolated dorsal pelvic ring fractures are rare. These fractures are usually combined with ventral pelvic ring or other fractures. Trauma mechanisms differ between young and old patients. Whereas a fall from stand can be a sufficient mechanism for an osteoporotic sacrum, great forces are needed in young patients. This results in a disruption of the iliosacral ligaments in young patients [1]. In old patients the ligaments usually remain intact leading to a different stability of the fractures [2].

Despite the differences between these patient groups, they are treated similarly. Because of multiple associated injuries young patients are often in a bad physical condition when admitted to surgery. To avoid a big second hit these fractures should be stabilised in a quick and minimally-invasive way whenever possible. Old patients with sacral fractures are often in a reduced general condition, which also requires the smallest procedure possible.

Different surgical techniques exist for fixation of sacral fractures [3]. With improvement of intraoperative imaging ORIF was gradually replaced by iliosacral screw (SI-screw) placement [4]. This resulted in a reduction of complications and operative trauma. Different techniques are available for percutaneous insertion. For standard fluoroscopic SI-screw placement a 2D-c-arm is required [5]. The complex anatomy of the pelvis and

* Corresponding author. Tel.: +49 731 500 54567; fax: +49 731 500 54502.
E-mail address: peter.richter@uniklinik-ulm.de (P.H. Richter).

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frequent changes in c-arm position (inlet, outlet, ap and lateral view) lead to high radiation doses [6].

With implementation of image guidance in orthopaedic theaters SI-screw accuracy could be increased [7]. 3D-navigation could furthermore reduce intraoperative radiation [8]. Thereby computer-assisted SI-screw insertion became the method of choice.

In recent years hybrid operating rooms were established all over the world. In our setting we combined a 3D flat-panel c-arm (Artis zeego, Siemens) with a navigation system (BrainLab curve, BrainLab). The flat-panel detector is fixed to the floor through a motorised robotic arm and digitally linked to the operating table as well as the navigation system (Fig. 1). In addition the hybrid-OR is completely controlled by the surgeon himself. This unique setting enables the surgeon to visualise the whole pelvis in CT-like image quality with a single 3D-scan [9].

The aim of our study was to investigate, if usage of a hybrid-operating room increases the accuracy of SI-screws in comparison to standard 3D-navigation.

Material and methods

Sixty one patients (35 female, 26 male) were included from June2012 till October 2014. Inclusion criterion was insertion of a percutaneous iliosacral screw using image-guidance in the hybrid operating room. Indications for implantation of a SI-screw ranged from iliosacral tumours to sacral fractures, iliosacral disruptions and sacral insufficiency fractures. A total of 65 iliosacral screws were inserted. One patient had to be revised because of SI-screw loosening after 84 days. Another patient had a screw removal and subsequent lumbopelvic instrumentation because of insufficient reduction of a dislocated sacral fracture. Four SI-screws were removed after healing of the fracture/iliosacral disruption (2 children, 2 young women). All intra- and postoperative complications as well as the operating time were documented. Furthermore the BMI and the age of the patients were noted.

The intraoperative setting was always the same. In all cases except for a tumour resection the patient was placed in a supine position with the dynamic reference base (DRB; BrainLab, Germany) fixed to the iliac crest. Afterwards a 3D-scan (Dyna CT) was performed using the Artis zeego (Siemens, Germany) and the images were automatically transferred to the navigation system (BrainLab Curve, BrainLab, Germany). After windowing of the images a verification of the data set was mandatory. In a next step the screws were planned and a 2.8 mm k-wire was inserted using a navigated drill sleeve. Subsequently another intraoperative 3D-scan was performed to verify the k-wire position and a 7.3 mm screw with washer was inserted. With this hybrid-OR it was possible to implant screws stabilizing not only one but both ilioscral joints with a single screw.

Fig. 1. Setting of the hybrid-OR: A floor-based robotic 3D-flatpanel-detector (1: Artis zeego, Siemens) is digitally linked the operating table and the navigation system (2: BrainLab curve, BrainLab), which is fixed to the ceiling.

Intraoperative 3D-scans and postoperative scans were examined to investigate screw placement. The most important factor was to identify cortical and neuroforaminal perforations. Perforation was divided into 4 groups according to Smith et al. [10]. Grade 0 implies no perforation, grade 1 a perforation <2 mm, grade 2 a perforation of 2–4 mm and grade 3 a perforation of >4 mm. Secondary the grade of deviation to the S1-endplate was documented and also divided in 4 groups. Grade 0 implies a deviation <5°, grade 1 a deviation of 5–10°, grade 2 a deviation of 11–15° and grade 3 a deviation of >15° (Table 1).

The results were compared to a preceding study performed in 2012 [11]. Forty nine patients with 74 SI-screws were included. All screws were inserted using a 3D-c-arm (Arcadis orbic 3D, Siemens Germany) in combination with a navigation system (BrainLab Vector Vision, BrainLab, Germany). All screws stabilised only 1 iliosacral joint/a unilateral fracture. Eighty five percent of the screws showed no perforation (grade 0), 3% grade 1, 4% grade 2 and 10% grade 3 perforation. There was an angulation less (grade 0) than 5° in 62%, grade 1 angulation in 30%, grade 2 in 5% and grade 3 angulation in 4% of all screws.

The study was approved by the ethics committee.

Statistics

Statistical calculations were performed using Microsoft Excel 2011 and SPSS (Version 20.0.0). Screws with grade 0 perforation and angulation were compared to screws with grade 1–3 combined. The graphs were generated using Microsoft Excel 2011.

Results

In 61 patients included in this study 65 iliosacral screws were implanted. Two different types of iliosacral screws were implanted: (1) Standard iliosacral screw stabilizing one joint/a unilateral fracture (Fig. 2). (2) Single SI-screw stabilizing both SI-joints and if present a bilateral fracture (Fig. 3).

Forty one patients could be included in the first group and received a single or two standard screws (screws $n = 45$). There was no perforation in 43 screws, grade 1 perforation in 2 screws. There was no grade 2 or 3 perforation in this group. Compared to the conventional 3D-navigated screws there was a highly significant difference ($p < 0.001$; Fig. 4). In group 1 there was grade 0 angulation in 30 screws, grade 1 angulation in 10 screws, grade 2 angulation in 5 screws and no grade 3 angulation. No statistical significance regarding angulation between screws implanted in the hybrid-OR and those implanted with conventional 3D-navigation could be seen.

Twenty patients could be included in group 2 receiving a single screw bridging both iliosacral joints. Eleven screws showed complete intraosseous position. There was grade 1 perforation

Table 1
Perforation and angulation according to Smith et al. [10].

	Grade 0	Grade 1	Grade 2	Grade 3
Perforation	No perforation	<2mm	2–4 mm	>4 mm
Angulation	<5°	5–10°	11–15°	>15°