

OPEN

Comparison of Isocentric C-Arm 3-Dimensional Navigation and Conventional Fluoroscopy for Percutaneous Retrograde Screwing for Anterior Column Fracture of Acetabulum

An Observational Study

Jiliang He, PhD, Guoqing Tan, PhD, Dongsheng Zhou, MD, Liang Sun, MD, Qinghu Li, PhD, Yongliang Yang, MD, and Ping Liu, MD

Abstract: Percutaneous screw insertion for minimally displaced or reducible acetabular fracture using x-ray fluoroscopy and computer-assisted navigation system has been advocated by some authors. The purpose of this study was to compare intraoperative conditions and clinical results between isocentric C-arm 3-dimensional (Iso-C 3D) fluoroscopy and conventional fluoroscopy for percutaneous retrograde screwing of acetabular anterior column fracture.

A prospective cohort study was conducted. A total of 22 patients were assigned to 2 different groups: 10 patients in the Iso-C 3D navigation group and 12 patients in the conventional group. The operative time, fluoroscopic time, time of screw insertion, blood loss, and accuracy were analyzed between the 2 groups.

There were significant differences in operative time, screw insertion time, fluoroscopy time, and mean blood loss between the 2 groups. Totally 2 of 12 (16.7%) screws were misplaced in the conventional fluoroscopy group, and all 10 screws were in safe zones in the navigation group. Percutaneous screw fixation using the Iso-C 3D computer-assisted navigation system significantly reduced the intraoperative fluoroscopy time and blood loss in percutaneous screwing for acetabular anterior column fracture.

The Iso-C 3D computer-assisted navigation system provided a reliable and effective method for percutaneous screw insertion in acetabular anterior column fractures compared to conventional fluoroscopy.

(*Medicine* 95(2):e2470)

Abbreviations: AP = anteroposterior, ASIS = anterior superior iliac spine, CT = computed tomography, Iso-C 3D = isocentric C-arm 3-dimensional, ORIF = open reduction and internal fixation, SEM = standard errors of the mean.

INTRODUCTION

Fractures of the acetabulum result primarily from high-energy trauma. The displaced acetabular fractures create an incongruity between the femoral head and acetabulum. Surgical treatment by open reduction and internal fixation (ORIF) is indicated for most displaced acetabular fractures, thus can restore the articular anatomy with rigid internal fixation, and allows early mobilization of the affected hip joint.¹ But open reduction and internal fixation require extensive exposure, which may bring about vascular or neural injury, profuse bleeding, infection, and heterotopic ossification.^{2,3} Percutaneous screw insertion for minimally displaced or reducible acetabular fracture using x-ray fluoroscopy and computer-assisted navigation system has been advocated by some authors.^{4–8}

The conventional percutaneous screwing for acetabular fractures requires multiplanar visualization for screw insertion, but x-ray fluoroscopy can only visualize 1 plane at a time. This prolongs the surgical time, and exposes patients and operating room personnel to radiation.^{4–7,9} The computer-assisted navigation system has been used for pelvic and acetabular fractures. Compared with conventional fluoroscopy, it provides more detailed images, enhance the accuracy, and decreases radiation exposure.^{7,8,10–12}

As far as we know, there is a few report on the use of the isocentric C-arm 3-dimensional (Iso-C 3D) fluoroscopy and the computer navigation system for the fractures of acetabulum. And there is less report about the comparison between Iso-C 3D fluoroscopy and conventional fluoroscopy in acetabular fractures. So, the purpose of this study was to compare Iso-C 3D fluoroscopy and conventional fluoroscopy for percutaneous retrograde screwing of acetabular anterior column fracture in intraoperative conditions and clinical results.

MATERIALS AND METHODS

Patients

The study protocol has been approved by the ethics review board of Provincial Hospital affiliated to Shandong University (No.2009SDSL017). All of the procedures conformed to the

Editor: Antonio Palazon-Bru.

Received: July 20, 2015; revised: December 3, 2015; accepted: December 14, 2015.

From the Department of Orthopaedic, Shandong Provincial Hospital Affiliated to Shandong University (JH, DZ, QL, YY); Department of Orthopaedic, Affiliated Hospital of Shandong University of Traditional Chinese Medicine (GT); Department of Urology, Shandong Provincial Hospital Affiliated to Shandong University (LS); and Department of Pharmacy, Shandong Provincial Hospital Affiliated to Shandong University, Jinan, China (PL).

Correspondence: Dongsheng Zhou, MD, Department of Orthopaedic, Shandong Provincial Hospital Affiliated to Shandong University, Jinan, China (e-mail: sdgkxxh@sina.com).

Correspondence: Dr. Ping Liu, MD, Department of Pharmacy, Shandong Provincial Hospital Affiliated to Shandong University, Jinan, China (e-mail: liupingmedicine@163.com).

Conflict of interest: Each author declares that they have no competing interests, and certifies that he has no commercial association (eg consultancies, stock ownership, equity interest, patent/licensing arrangement, etc) that might pose a conflict of interest in connection with the submitted article.

Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved. This is an open access article distributed under the Creative Commons Attribution-NonCommercial-NoDerivatives License 4.0, where it is permissible to download, share and reproduce the work in any medium, provided it is properly cited. The work cannot be changed in any way or used commercially.
ISSN: 0025-7974
DOI: 10.1097/MD.0000000000002470

ethical standards established in the Declaration of Helsinki (1964) and relevant policies in China. Written informed consent was obtained from all study participants. From July 2008 to October 2012, we retrospectively analyzed 22 patients with acetabular anterior column fractures who were treated by percutaneous screwing. The inclusion criteria in this study included all patients admitted to our institution presenting with mildly displaced acetabular anterior column fractures or transverse acetabular fractures, which could be reduced by the close method or minimally invasive technique. Patients were divided into 2 subgroups depending on the method of intraoperative fluoroscopy that was chosen based on experience and preference of the operating surgeon. Ten patients were operated with Iso-C 3D fluoroscopy and the computer navigation system. Twelve patients were operated with conventional C-arm fluoroscopy (BV25 GOLD, Philips, The Netherlands). All procedures were carried out by surgeon (Zhou and Yang) in our department. Patients' demographic details, injury mechanism, associated injuries, and interval between injury and operation were recorded.

Operative Technique

Resuscitation, active treatment of complications, and temporary treatment of fracture were implemented on admission. If a displaced acetabular fracture was diagnosis, femoral traction with 9–13 kg was performed. The operation was performed after the symptoms of associated injuries disappeared, and general condition was stable. Preoperative radiological evaluation included anteroposterior (AP), iliac oblique and obturator oblique view, and a computed tomography (CT) scans.

Navigation Group

The patient was placed on the fracture table with traction in a supine position after general anesthesia. The image guidance dynamic reference array with the radiolucent head frame was fixed tightly on 2 percutaneously placed 3.0 mm Kirschner wires in the iliac crest at the same side of the fracture for registration (Figure 1). Great care was taken to avoid movement of the reference array. In order to acquire accurate images, the injured side of pelvis must be in the center of the images of the Iso-C 3D



FIGURE 1. The fixation of the reference array. The reference array was fixed tightly on 2 percutaneously placed 3.0 mm Kirschner wires in the iliac crest.

fluoroscopy at the AP and lateral views. Afterward, Iso-C 3D imaging was performed after the operating room personnel left the operating room. During scanning, the motorized C-arm moved continuously ~190 degrees and multiplanar reconstructions were generated. The images were automatically transferred to the Stealth-Station Treatment Guidance Platform System (Medtronic, Sofamor Danek, Broomfield, CO). Afterward, the drill and guide device with the radiolucent head were registered in the Iso-C 3D navigation system. The skin incision position and screw trajectory were planned based on the 3D reconstructed images (Figure 2). A 3 cm skin incision was performed at the planned position. A guide wire controlled by navigation was placed. Then the position of the guide wire was verified by conventional x-ray fluoroscopy in different views. We then drilled the hole with cannulated drill and inserted an AO 6.5 mm cannulated screw. The position of the screw was verified by fluoroscopy and removed the guided wire (Figure 3).

Conventional Group

The screw was placed percutaneously with the patient in the supine position on the fracture table. The same surgeon performed the conventional operation for screw insertion using C-arm fluoroscopy. Standard AP and inlet fluoroscopic pelvic views were obtained. By rotating these views, the direction of screw was determined and a guided wire was placed. We then drilled the hole with a cannulated drill followed by insertion of a 6.5 mm cannulated screw.

Postoperative Evaluation

Data on the fluoroscopic time, time of screw insertion, operative time, blood loss, procedural complication, and clinical outcome were collected. Operative time was obtained from the anesthesia record and was defined as the time from anesthesia accomplished to closure of the incision. The time of the screw insertion was defined as the duration from the beginning of guide wire placement to the successful insertion of screw. Postoperative pelvic radiographs and CT images (Figure 4) were obtained for all patients in the hospitalization period. All images were evaluated by 2 independent investigators. Assessment of screws perforation was classified as grade 0 (no perforation), grade 1 (perforation <2 mm), grade 2 (perforation 2–4 mm), and grade 3 (perforation >4 mm).¹³ Postoperative functional recovery was assessed using the modified Merle d'Aubigné and Postel score:¹⁴ very good (11–12), good (10), medium (9), fair (8), and poor (<8).

Statistical Analysis

Differences in the operative time, fluoroscopic time, blood loss and time of screw insertion were described as mean \pm standard errors of the mean (SEM) and compared using Student's *t* test. Categorical variables were compared using Fisher's exact test. For statistical analysis, SPSS17.0 software (SPSS Company, USA) was used. Statistical significance was defined as $P \leq 0.05$.

RESULT

Patient Characteristics

In this study, 10 patients underwent a procedure with Iso-C 3D fluoroscopy and 12 patients with conventional C-arm fluoroscopy. There were 15 men and 7 women, with an average age of 35.6 ± 11.4 years. The demographics and preoperative

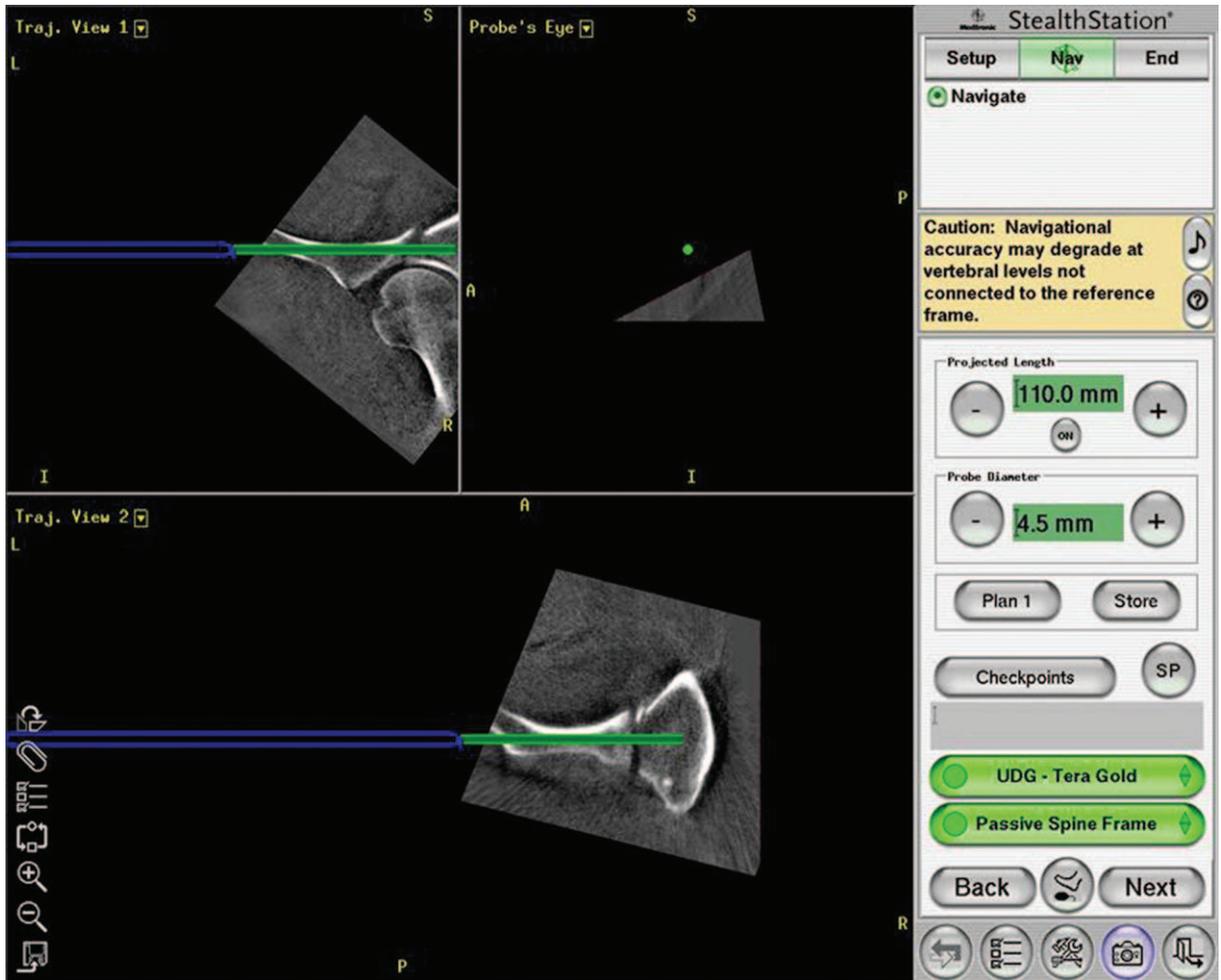


FIGURE 2. The 3D reconstructed images. Reconstructed multiplanar images obtained by the isocentric C-arm and used for image-guided navigation during acetabular anterior column percutaneous screw insertion in the transverse, coronal, and sagittal image planes.

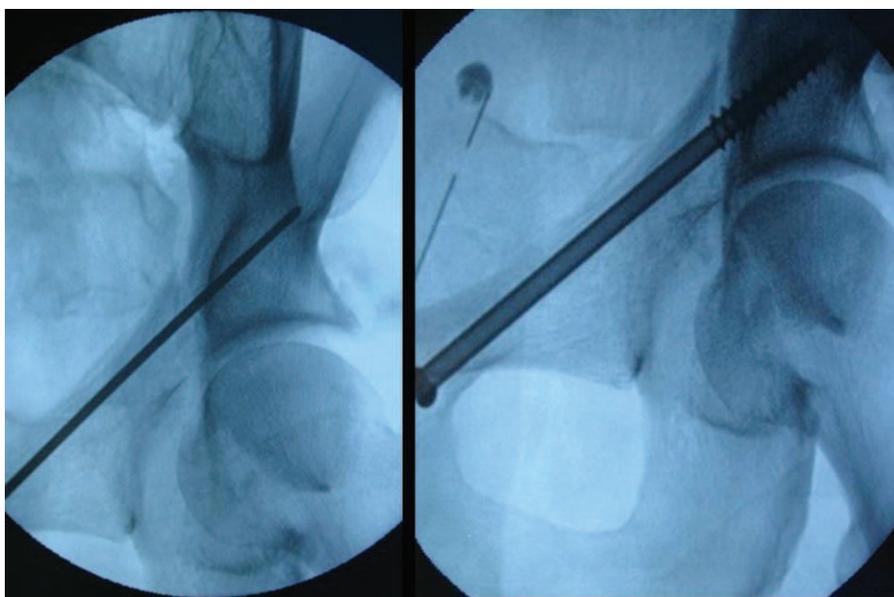


FIGURE 3. The images in the operation. The intraoperative x-ray confirmed the placement of guided wire and screw when using isocentric C-arm 3-dimensional fluoroscopy.

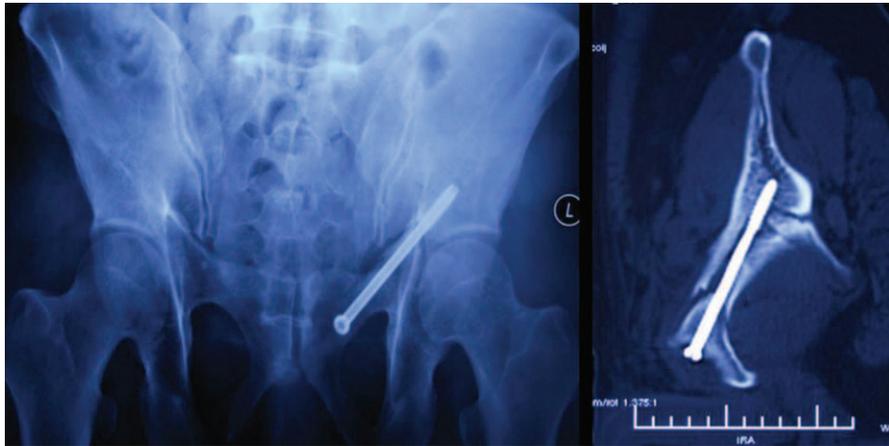


FIGURE 4. Postoperative images. The postoperative x-ray and CT scan confirmed the placement of acetabular anterior column screw. CT=computed tomography.

variables were summarized in Table 1. There were no significant differences in age, gender, injury mechanism, associated injuries, and interval between injury and operation. According to the Letournel classification, all of the fractures involved with anterior column fracture of acetabulum, which were nondisplaced or mildly displaced.

Operative Records

The average operative time was 34.0 ± 5.9 min (25–45 min) in the Iso-C 3D fluoroscopy group and 35.7 ± 7.0 min (28–50 min) in the conventional fluoroscopy group ($P = 0.550$). The mean fluoroscopic time in the Iso-C 3D fluoroscopy group was 26.9 ± 2.1 s compared with 80.7 ± 3.0 s in the conventional fluoroscopy group ($P < 0.001$). The mean time of screw insertion was 7.8 ± 2.1 min in the Iso-C 3D fluoroscopy group and 15.5 ± 6.0 min in the conventional fluoroscopy group ($P = 0.001$). The intra-operative blood loss averaged 22.0 ± 4.8 mL in the Iso-C 3D fluoroscopy group and 45.0 ± 13.9 mL in the conventional fluoroscopy group ($P < 0.001$) (Table 2).

Radiographic Assessment

The accuracy of screws position was evaluated by 2 independent investigators based on the postoperative CT scans. There were 10 screws placed in the Iso-C 3D fluoroscopy group, all screws were inserted in the acetabular anterior column without perforation out of the cortex. Twelve screws were placed in the conventional fluoroscopy group. And 2 of 12 (16.7%) screws were classed as grade 3, they both penetrated out of the anterior cortex of acetabular anterior column (Figure 5), but no associated complications were observed in both cases.

Complications

No vascular or neural injury was observed during and after operation. No screw penetrated into the hip joint. Although we observed that 2 screws penetrated out of the anterior cortex of acetabular anterior column in the conventional fluoroscopy group, there were no associated complications observed.

TABLE 1. Demographic Characteristics

Parameter	Iso-C 3D (n = 10)	C-arm (n = 12)	P Value
Gender, number (%)			0.870
Male	7 (70.0%)	8 (66.7%)	
Female	3 (30.0%)	4 (33.3%)	
Age, year	33.6 ± 11.9	37.3 ± 11.3	0.459
Injury mechanism, number (%)			0.893
Traffic accident	5 (50.0%)	6 (50.0%)	
Fall	2 (20.0%)	3 (25.0%)	
Crush	3 (30.0%)	3 (25.0%)	
Associated injuries, number (%)			0.533
Head injury	2 (20.0%)	2 (16.7%)	
Thoracic injury	3 (30.0%)	4 (33.3%)	
Abdominal injury	1 (10.0%)	0 (0.0%)	
Nil	4 (40.0%)	6 (50.0%)	
Interval between injury and operation, day	4.4 ± 1.9	4.8 ± 1.9	0.595

Iso-C 3D = isocentric C-arm 3-dimensional.

TABLE 2. Operative and Result Characteristics

Parameter	Iso-C 3D (n = 10)	C-arm (n = 12)	P Value
Procedure time (min)	34.0 ± 5.9	35.7 ± 7.0	0.550
Screw insertion time (min)	7.8 ± 2.1	15.5 ± 6.0	0.001
Fluoroscopic time (s)	26.9 ± 2.1	80.7 ± 3.0	<0.001
Blood loss (mL)	22.0 ± 4.8	45.0 ± 13.9	<0.001
Implanted screws of acetabular anterior column			
Total	10	12	0.481
Failed	0	2	
Postoperative outcome*			0.594
Excellent	9	9	
Good	1	3	

Iso-C 3D = isocentric C-arm 3-dimensional.

* According to the modified Merle d’Aubigné and Postel score.

Clinical Outcome

All patients felt pain free 3 days after the operation. Patients were followed up at first, third, and sixth month after operation and then every 6 months. In our study, all 22 cases were followed up at 12 to 42 months after the operation with a mean follow-up time of 26.2 months. Functional assessment was rated at postoperative 12 months according to the modified

Merle d’Aubigné and Postel score,¹⁴ there were 9 cases very good and 1 case good in the Iso-C 3D fluoroscopy group compared with 9 cases very good and 3 cases good in the conventional fluoroscopy group (*P* = 0.375).

DISCUSSION

In our study, the results demonstrate that percutaneous screw fixation for the acetabular anterior column fracture with Iso-C 3D fluoroscopy and x-ray fluoroscopy has similar positioning accuracy. Insertion of percutaneous screws with Iso-C 3D fluoroscopy is accompanied by relatively reduced fluoroscopy time and less blood loss.

According to the Judet and Letournel classification of acetabular fracture,^{15,16} an anterior column fracture is defined as fracture line running from anterior superior iliac spine (ASIS) to superior pubic ramus. Although nondisplaced or mildly displaced acetabular anterior column fractures can be treated conservative management, patients with these fractures have a high risk of fracture dislocation under weightbearing. Without operative treatment, these patients need to lie in bed for several weeks, and thus may result in some associated complications. Therefore, nondisplaced or mildly displaced acetabular anterior column fractures are still treated by operative stabilization in our department.

The main goal of operative treatment for acetabular fractures is to obtain anatomical reduction and rigid internal fixation.^{1,16} Open reduction and internal fixation can achieve an expected gain, but extensive exposure leads to many associated complications, including femoral vascular injury, femoral nerve injury, lateral femoral cutaneous nerve injury, obturator nerve and artery injury, greater blood loss, infection,



FIGURE 5. The misplaced screws. Postoperative CT images showing the position of the acetabular anterior column screw using conventional C-arm fluoroscopy; the screw breaches out of the acetabular anterior column cortical wall (arrows). CT = computed tomography.

heterotopic ossification, and inguinal hernia. ORIF for nondisplaced or mildly displaced acetabular anterior column fractures may lose more than it gains. Therefore, percutaneous screw insertion with x-ray fluoroscopy or computer-assisted navigation system had been performed for nondisplaced or mildly displaced acetabular fractures.^{4–12} However, the use of percutaneous screw insertion with x-ray fluoroscopy or computer-assisted navigation system exposes the patients and surgeons to a significant amount of radiation, and has the risk of screw penetration. Dose either Iso-C 3D fluoroscopy system or x-ray fluoroscopy have more advantages of reducing radiation time and improving screw position?

The computer-assisted navigation system has been applied to treat some pattern of acetabular fractures. On the accuracy of percutaneous screw implantation, Kahler and Zura showed that the computer-assisted navigation system improved screw position, had comparable accuracy to CT guided technique in a cadaveric study.¹⁷ And Ulrich Stöckle et al reported the similar conclusion, percutaneous screw insertion with navigation system had more accuracy compared with conventional fluoroscopy system for acetabular fractures.¹⁸ However, Ochs et al reported that accuracy of percutaneous screw was similar regardless of the imaging method for the acetabular anterior column screw.¹⁹ In our study, the screw implantation accuracy was improved when using Iso-C 3D fluoroscopy system as compared to conventional x-ray fluoroscopy, but not significantly ($P=0.186$). We thought that the images of acetabular anterior column were acquired easier and more detailed as compared to acetabular posterior column and iliosacral joint when using conventional x-ray fluoroscopy, and thus may improve percutaneous screwing accuracy in anterior column of acetabulum.

Some studies have reported that percutaneous screw implantation with navigation system for acetabular fractures reduced radiation exposure time as compared with conventional x-ray fluoroscopy. Frank et al reported the fluoroscopy time of 180 ± 13 s in percutaneous screwing for acetabular anterior column by x-ray fluoroscopy only.²⁰ And Mouhsine et al revealed a mean fluoroscopy time of 62 s (55–80 s) in percutaneous screwing for acetabular fractures with fluoroscopy only.²¹ Comparatively, Yu-Chuan Lin et al revealed a mean fluoroscopy time of 38 s (35–45 s) in percutaneous screwing with fluoroscopy-based computerized navigation system for acetabular anterior column fractures.²² Hong et al reported a mean fluoroscopy time of 28.5 s (11–58 s) in percutaneous screw fixation of acetabular fractures with 2D fluoroscopy-based computerized navigation.²³ In our study, the radiation exposure time was reduced using the Iso-C 3D fluoroscopy system (26.9 ± 2.1 s) compared to the conventional fluoroscopy technique (80.7 ± 3.0 s). The Iso-C 3D fluoroscopy system reduced the radiation exposure time for the patients, surgeons, and operating room personnel. And the operating room personnel left the operating room when the Iso-C 3D scan was started, so they received no radiation during the scanning procedure. In addition, intraoperative blood loss was also recorded in our study. The blood loss was less using the Iso-C 3D fluoroscopy system compared to conventional fluoroscopy ($P < 0.001$). We thought, reduced radiation time and less blood loss were related to shortened screw insertion time in the Iso-C 3D fluoroscopy group. In our study, the screw insertion time was significantly short using the Iso-C 3D fluoroscopy system (7.8 ± 2.1 min) compared to conventional fluoroscopy (15.5 ± 6.0 min) (Figure 6). In the conventional group, surgeons needed to obtain multiple image planes including AP, inlet,

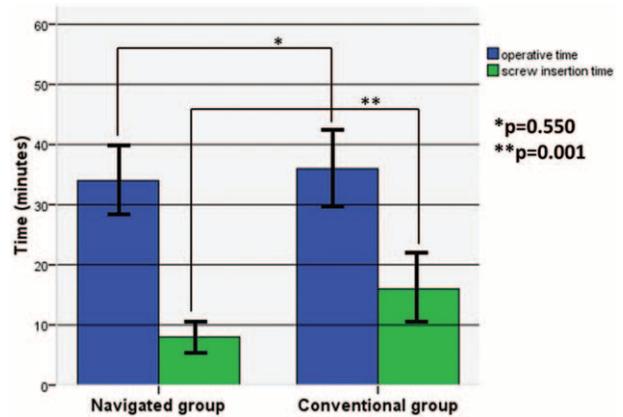


FIGURE 6. Comparison between navigation group and conventional group in operative time and screw insertion time. A graph shows operative time and screw insertion time measured in minutes in the navigated and conventional groups. The operative time was similar ($P=0.550$) in the navigated and conventional groups. But the screw insertion time was shorter ($P=0.001$) in the navigated group than in the conventional group.

outlet, iliac oblique and obturator oblique views. However, it was not possible to require multiplanar radiographic images simultaneously. To confirm the screw position, an assistant must not stop changing the radiographic image among the multiplanar images during the operation. Thus it increased the difficulty of the procedure and prolonged the screw insertion time. By contrast, the Iso-C 3D fluoroscopy system could obtain multiplanar images of the operative area including transverse, coronal and sagittal image planes simultaneously, and obtain more detailed fluoroscopic images,^{18,24} thus simplified the procedure of percutaneous screwing, reduced the rate of revision, and shortened the screw insertion time. Therefore, using the Iso-C 3D fluoroscopy system needs to prepare the navigation system, but does not prolong the total operative time compared to conventional fluoroscopy ($P=0.550$).

Despite our findings, there are still limitations of using the Iso-C 3D computer assisted navigation system. In our study, the sample size was not large enough, so more cases are needed to reach a more convincing conclusion. And the patients were not randomized into 2 groups, but according to their requirement. In addition, the Iso-C 3D computer navigation system is more expensive, this might be a burden on some patients. Intraoperative confirmation by conventional fluoroscopy should be needed, because an unnoticed displacement of the reference array can lead to a complete shift of the images. The technique of Iso-C 3D computer navigation system cannot be used to reduce the obvious displaced fractures.

CONCLUSION

Though there are still limitations of using Iso-C 3D computer-assisted navigation system, compared to conventional intraoperative fluoroscopy, the Iso-C 3D computer assisted navigation system reduces the total radiation exposure time for patients and surgeons, and decreases the intraoperative blood loss for the patients with mildly displaced acetabular anterior column fracture. Iso-C 3D computer-assisted navigation system had a decreased risk for surgical complication for the acetabular fracture patients who need minimally invasive percutaneous

screw fixation. The Iso-C 3D computer navigation system is reliable and effective, and shows some benefits compared to the conventional fluoroscopy.

ACKNOWLEDGMENTS

The authors sincerely thank Dr Wensi Hu for helping us in statistical analysis in this study.

REFERENCES

- Matta JM, Merritt PO. Displaced acetabular fractures. *Clin Orthop Relat Res.* 1988;230:83–97.
- Helfet DL, Borrelli J Jr, DiPasquale T, et al. Stabilization of acetabular fractures in elderly patients. *J Bone Joint Surg Am.* 1992;74:753–765.
- Kaempffe FA, Bone LB, Boredr JR. Open reduction and internal fixation of acetabular fractures: heterotopic ossification and other complications of treatment. *J Orthop Trauma.* 1991;5:439–445.
- Roult ML Jr, Simonian PT, Grujic L. The retrograde medullary superior pubic ramus screw for the treatment of anterior pelvic ring disruptions: a new technique. *J Orthop Trauma.* 1995;9:35–44.
- Parker PJ, Copeland C. Percutaneous fluoroscopic screw fixation of acetabular fractures. *Injury.* 1997;28:597–600.
- Starr AJ, Reinert CM, Jones AL. Percutaneous fixation of the columns of the acetabulum: a new technique. *J Orthop Trauma.* 1998;12:51–58.
- Crowl AC, Kathler DM. Closed reduction and percutaneous fixation of anterior column acetabular fractures. *Comput Aided Surg.* 2002;7:169–178.
- Stöckle U, König B, Dahne M, et al. Computer assisted pelvic and acetabular surgery. Clinical experiences and indications. *Unfallchirurg.* 2002;105:886–892.
- Evans AR, Pape HC. Percutaneous fixation of geriatric acetabular fractures. *Oper Tech Orthop.* 2011;21:265–271.
- Ruan Z, Luo CF, Zeng BF, et al. Percutaneous screw fixation for the acetabular fracture with quadrilateral plate involved by three-dimensional fluoroscopy navigation: surgical technique. *Injury.* 2012;43:517–521.
- Jacob AL, Suhm N, Kaim A, et al. Coronal acetabular fractures: the anterior approach in computed tomography-navigated minimally invasive percutaneous. *Cardiovasc Intervent Radiol.* 2000;23:327–331.
- Mosheiff R, Khoury A, Weil Y, et al. First generation computerized fluoroscopic navigation in percutaneous pelvic surgery. *J Orthop Trauma.* 2004;18:106–111.
- Smith HE, Yuan PS, Sasso R, et al. An evaluation of image-guided technologies in the placement of percutaneous iliosacral screws. *Spine.* 2006;31:234–238.
- Merle d'Aubigné R, Postel M. Functional results of hip arthroplasty with acrylic prosthesis. *J Bone Joint Surg Am.* 1954;36-A:451–475.
- Judet R, Judet J, Letournel E. Fractures of the acetabulum—Classification and surgical approaches for open reduction: a preliminary report. *J Bone Joint Surg Am.* 1964;46:1615–1636.
- Letournel E. Acetabulum fractures: classification and management. *Clin Orthop Relat Res.* 1980;151:81–106.
- Kahler DM, Zura R. Evaluation of a computer integrated surgical technique for percutaneous fixation of transverse acetabular fractures. *Lect Notes Comput Sci.* 1997;1205:565–572.
- Stöckle U, Schaser K, König B. Image guidance in pelvic and acetabular surgery—expectations, success and limitations. *Injury.* 2007;38:450–462.
- Ochs BG, Gonsler C, Shiozawa T, et al. Computer-assisted periacetabular screw placement: comparison of different fluoroscopy-based navigation procedures with conventional technique. *Injury.* 2010;41:1297–1305.
- Frank M, Dedek T, Trlica J, et al. Percutaneous fixation of anterior column acetabular fractures—first experience. *Acta Chir Orthop Traumatol Cech.* 2010;77:99–104.
- Mouhsine E, Garofalo R, Borens O, et al. Percutaneous retrograde screwing for stabilisation of acetabular fractures. *Injury.* 2005;36:1330–1336.
- Lin YC, Chen CH, Huang HT, et al. Percutaneous antegrade screwing for anterior column fracture of acetabulum with fluoroscopic-based computerized navigation. *Arch Orthop Trauma Surg.* 2008;128:223–226.
- Hong G, Cong-Feng L, Cheng-Fang H, et al. Percutaneous screw fixation of acetabular fractures with 2D fluoroscopy-based computerized navigation. *Arch Orthop Trauma Surg.* 2010;130:1177–1183.
- Kendoff D, Gardner MJ, Citak M, et al. Value of 3D fluoroscopic imaging of acetabular fractures comparison to 2D fluoroscopy and CT imaging. *Arch Orthop Trauma Surg.* 2008;128:599–605.