

Accuracy and safety of percutaneous periacetabular screw insertion using screw view model of navigation in acetabular fracture

A case report

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Abstract

Rationale: The purpose of this study was to estimate the efficacy and safety of percutaneous periacetabular screw (PPS) insertion assisted by screw view model of navigation (SVMN) to treat fracture of acetabulum.

Patient concerns: A 61-year-old male patient was injured in a motorcycle accident, which caused pain, swelling, deformity and limited mobility on his right hip.

Diagnoses: He was diagnosed with fracture of acetabulum.

Interventions: We used PPS insertion assisted by SVMN to treat fracture of acetabulum in this patient.

Outcomes: The follow up lasted 24 months. Totally 2 screws were inserted into anterior and posterior column of acetabulum respectively and both of them displayed grade 0. Compared with the preoperative gap and step of fracture displacement, the postoperative ones were significantly reduced. It took 11.7 minutes for designing the screws, 6.7 minutes for implanting the guide wire, and 45.5 minutes for placing the screws. Intraoperative blood loss was 29 mL and total fluoroscopic time was 4.1 minutes. No clinical complications such as nerve vascular injury, infection and screw loosening were found after the operation.

Lessons: The study indicated that SVMN is favorable to the PPS insertion for acetabular fracture. Our lesson is that the relative position between the acetabular and the patient tracker must be static to ensure the accuracy of the entire system throughout the operation.

Abbreviations: 3D = 3 dimensional, CT = computed tomography, ORIF = open reduction and internal fixation, PPS = percutaneous periacetabular screw, SVMN = screw view model of navigation.

Keywords: acetabular fracture, navigation, percutaneous, periacetabular screw

1. Introduction

Acetabular fractures often result in damage to hip joint. To achieve anatomical reduction and rigid internal fixation, open reduction and internal fixation (ORIF) are often used. However, they are accompanied by many complications such as neurovascular injury,^[1-5] infection,^[6,7] bleeding,^[8] and heterotopic ossification.^[9,10] According to literature reports, the complica-

tions of ORIF are as high as 70%.^[11] In order to reduce the incidence of complications, Caviglia H et al^[12] used minimally invasive percutaneous cannulated screw fixation, but this technique has disadvantages of long operation time and large radiation exposure to patients and doctors. These problems could be solved, as reported in the research, by performing the percutaneous minimally invasive internal fixation for the treatment of acetabular fractures under computer-aided navigation, which can significantly reduce the radiation exposure and shorten the operation time.^[13]

The purpose of this study is to explore the accuracy and safety of screw view model of navigation (SVMN) applied in the operation of acetabular fracture that performed by inexperienced surgeons. In this screw view model, the navigation monitor displays the static axial, sagittal, and coronal 3 dimensional (3D) computed tomography (CT) of acetabular fracture with designed screws, which makes the manipulation simple and accurate. As far as we know, the application of this novel technology with percutaneous periacetabular screw (PPS) placement has been rarely reported.

2. Patients and methods

2.1. Ethical approval

The Second Hospital of Jilin University, Changchun, China, approved the study and the institutional guidelines for the care

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There is no conflict of interest in this study.

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Table 1**The basic information of the patient.**

Parameter	Case
Age, year	61
Gender, male/female	Male
Screw position, grade 0/1/2/3	grade 0 (100%)
Screw designing time, min	6.3 (anterior column); 5.4 (posterior column)
Screw insertion time, min	21.4 (anterior column); 24.1 (posterior column)
Guide needle insertion time, min	2.9 (anterior column); 3.8 (posterior column)
Blood loss, mL	29
Fluoroscopic time, min	4.1
Infection	None
Screw loosening	None
Follow up, month	24

and treatment of patients were rigorously followed. Informed written consent was obtained from the patient for publication of this case report and accompanying images.

2.2. Case report

A 61-year-old male patient was injured in a motorcycle accident (Table 1), which caused pain, swelling, deformity and limited mobility on his right hip. Examination revealed that the lateral side of right leg and the right dorsum were hyposensitive, and the skin in the perineum saddle and the inside of both thighs were normal. The muscle strength of both the right anterior tibialis and the right extensor pollicis longus were indicated as 0, the pulse of dorsal artery and the posterior tibial artery were good, and positive results of pelvic distraction and compression test were obtained.

In accordance with the x-ray image as shown in Figure 1, the left acetabular bone was discontinuous and irregular, while the right acetabular bone was also discontinuous, the right femoral head was displaced upward, the cortex of the superior branch and the inferior branch of the right pubic ramus were discontinuous, and the space between right sacroiliac joints was increased. X-ray examination was performed preoperatively and postoperatively.

The patient was primarily diagnosed as bilateral acetabular fracture, right suprapubic symphysis, and inferior branch

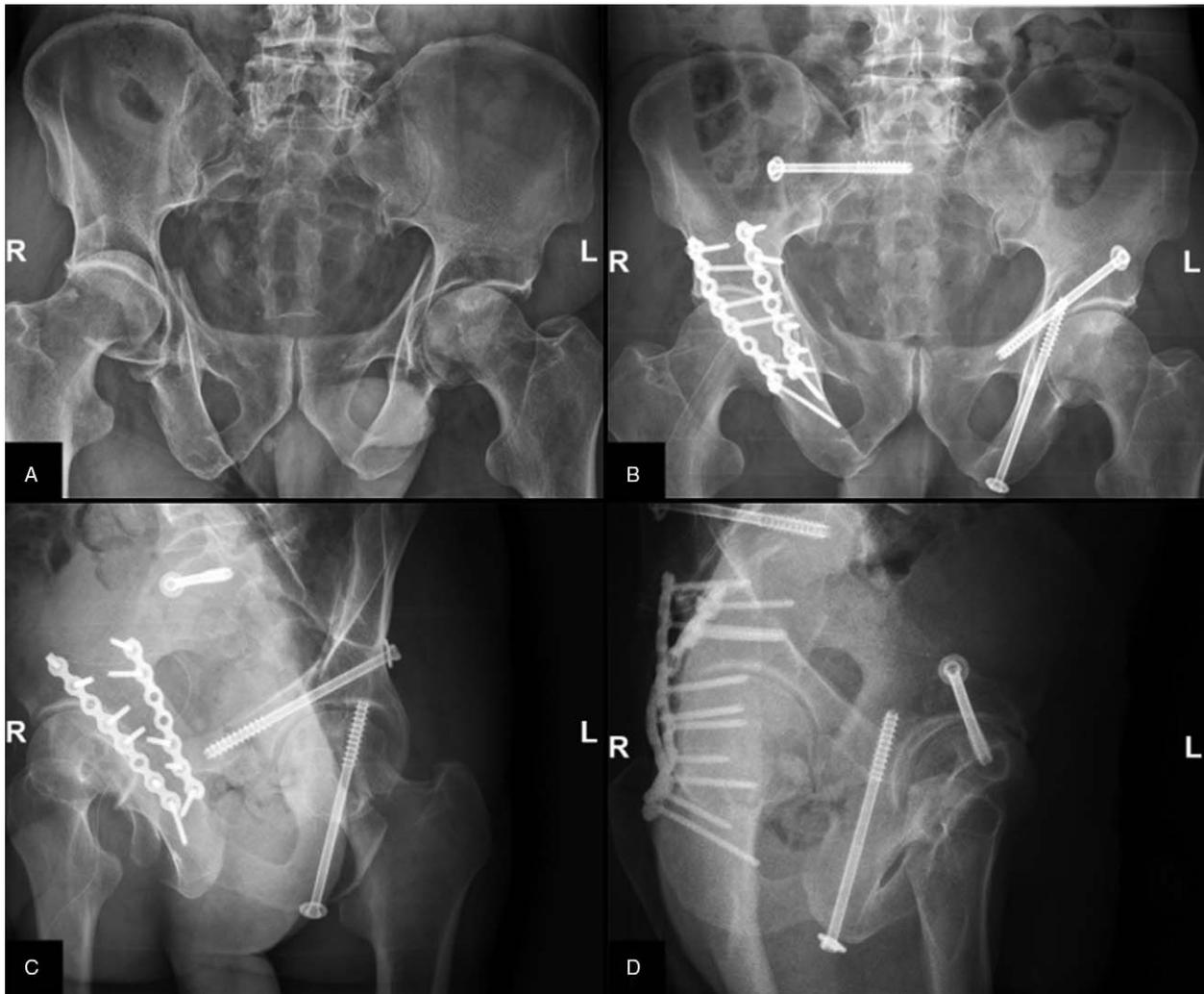


Figure 1. X-ray of pelvis. A 61-year-old male patient was injured in a motorcycle accident. (A) According to the preoperative x-ray image, both the left and right acetabulum were fractured, the right femoral head was displaced upward, the right pubic ramus was fractured, and the space between the right sacroiliac joints was widened. Postoperative x-ray images (B–D) show that the 2 screws around acetabulum are in good positions.

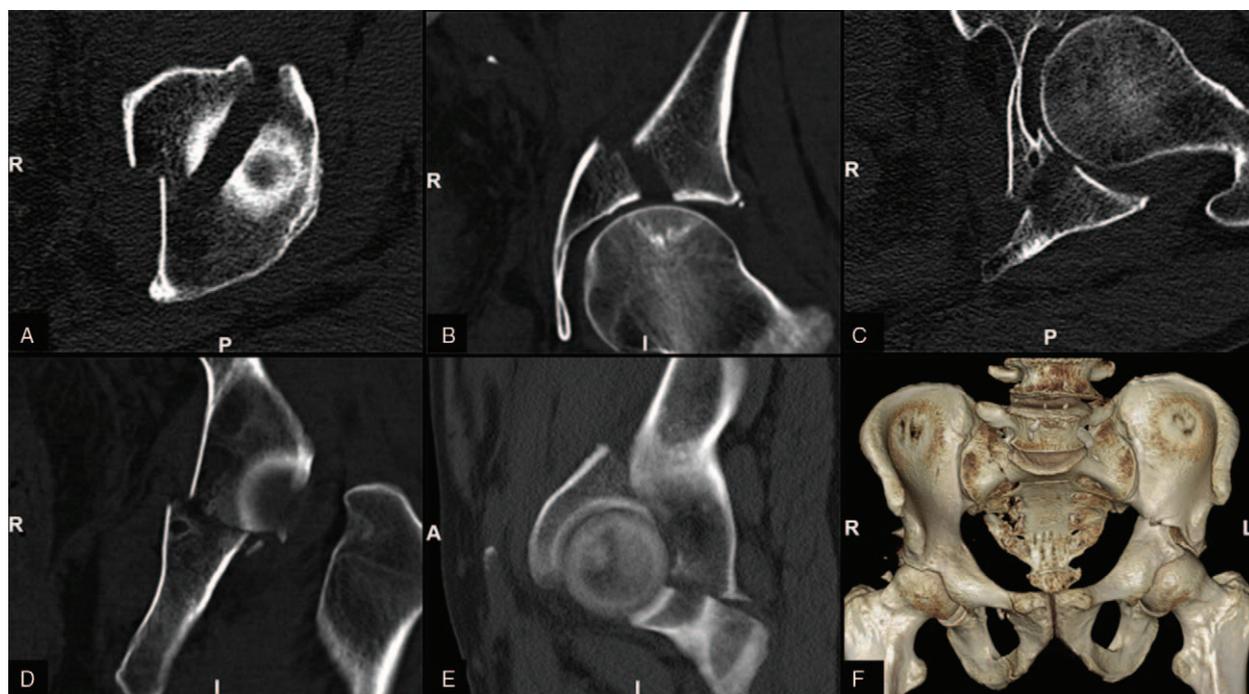


Figure 2. Preoperative 3D CT examination of pelvis. (A) The axial plane of anterior acetabular column displayed that the displacement gap of fracture was 9.8 mm, (B) The coronal plane of anterior acetabular column displayed that the displacement gap of fracture was 8.0 mm and the step was 0.2 mm, (C) The axial plane of posterior acetabular column displayed that the displacement gap of fracture was 7.8 mm, (D) The coronal plane of posterior acetabular column displayed that the displacement gap of fracture was 7.3 mm and the step was 2.9 mm, (E) The sagittal plane of acetabular fracture, (F) The 3D reconstruction image of pelvis. 3D=3 dimensional, CT=computed tomography.

fracture, displacement of right sacroiliac joint, dislocation of the right hip joint, and right sciatic nerve injury.

The whole pelvis was scanned by CT preoperatively, and the result was as shown in Figure 2. The image data was recorded in the disc that could be recognized by a computer navigation system. The diameter, length and the best trajectory of the PPS were designed at the navigation workstation preoperatively (Fig. 3). In addition, intraoperative neurophysiologic monitoring was used.^[14]

2.3. Surgical procedures

The operation was performed under general anesthesia (intubation: propofol, 200 μ g/kg, Fresenius Kabi Deutschland GmbH, Bad Homburg v.d.H. Germany; fentanyl, 250 μ g, RenFu LLC, YiChang, China; midazolam, 2mg; maintenance: propofol, 0.2 to 0.5 mg/kg/h, Enhua Pharmaceutical Limited by Share Ltd., JiangSu, China). Short-acting muscle relaxants were provided only during the intubation. When the anesthesia came into effective, the patient was placed in the supine position.

First, a patient tracker (Stryker Leibinger GmbH & Co., Freiburg, Germany), which operated with the Navigation System II-CART II with SpineMap 3D 2.0 software (Stryker Navigation, Kalamazoo, MI, USA), was fixed on the iliac crest or the pelvic frame at the beginning of the operation. The system's C-arm tracker, patient tracker, and guide wire sleeve tracker were all activated. After 190° scanning was performed at the center of the lumbosacral articular surface, 3D images of the lesion were obtained. After that, preoperative and intraoperative CT images were matched to provide clear guidance for the screws. The position of the ipsilateral pubic tubercle was selected as the

insertion region, which is one of so-called safe-zones (anterior column), and the posterior 1/3 of the sciatic tubercle was selected as an alternative, which is another one of so-called safe-zones (posterior column). About 1.5 cm of the incision had been made around the insertion region of guide wire, blunt separation between subcutaneous tissue and the bone surface and insertion of a guide needle sleeve.

Second, the screw view mode was selected in the navigation workstation (Fig. 4) and the position of the guide wire sleeve device was adjusted until the direction of guide wire sleeve was completely consistent with the planning PPS trajectory and the guide wire was placed once the right lower corner image showed green (Fig. 4). At the end of the operation, partially threaded cannulated titanium screws that designed preoperative with washers were inserted and tightened sequentially through the implanted guide wire.

Finally, the patient underwent the postoperative 3D CT scanning and the results were as demonstrated in Figure 5. On the second day after surgery, the patient had been advised to do some exercises such as static muscle contraction and passive joint exercises within limited range of activity. Partly weight-bearing exercise can be done 4 weeks after surgery.

2.4. Evaluation and result

Evaluation of screws position was classified as 4 grades: grade 0 (no perforation), grade 1 (perforation <2mm), grade 2 (perforation 2–4mm), and grade 3 (perforation >4mm).^[15] The gap and the step displacement of the fractures were calculated in 3 standardized planes (anterior-posterior, coronal, and sagittal),^[16] the reduction of acetabular was classified as

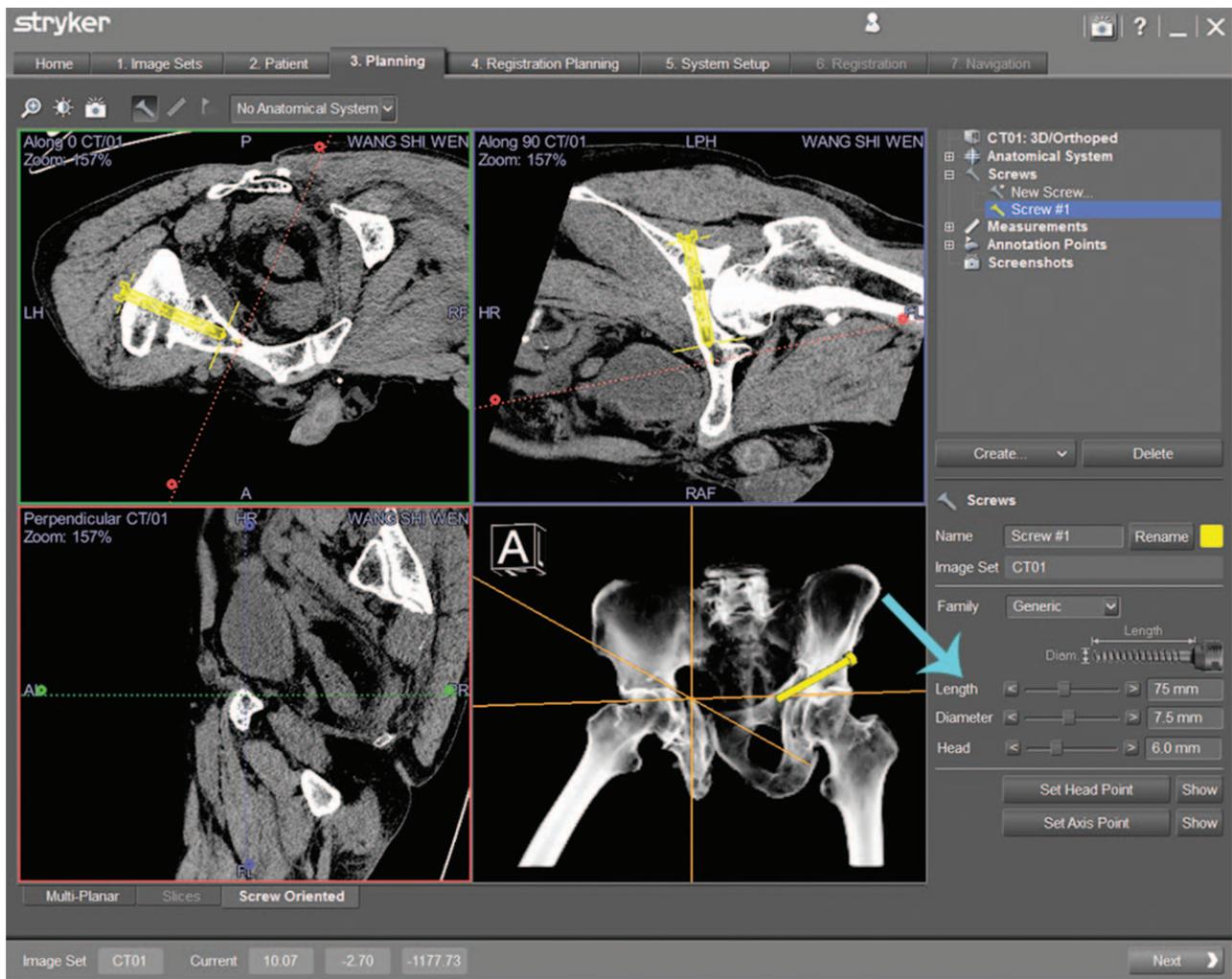


Figure 3. The length, diameter (blue arrow) and the best trajectory of screws were determined before the operation.

following 3 grade according to the distance of gaps and steps, unsatisfactory (>3 mm), imperfect (1–2 mm), and perfect (<1 mm).^[7] Also, the time for designing the screws, implanting the guide wire, and inserting the screws, amount of bleeding, and fluoroscopic time were evaluated.

The postoperative 3D CT shows that the 2 implanted screws were both in position of grade 0. The preoperative fracture displacement of gap and step was improved to perfect and imperfect postoperative, there was no unsatisfactory reduction and details are listed in Table 2. It took 11.7 minutes for designing those 2 screws, 6.7 minutes for implanting the guide wires, and 45.5 minutes for inserting the screws. The amount of bleeding was 290 mL including 261 ml of open reduction of right acetabular fracture and 29 mL of periacetabular screws, and fluoroscopic time was 4.1 minutes. No complications were found during 24 months of follow up, such as neurological injury, vascular injury, infection on the inside of articular surface, and screw loosening or breakage.

3. Discussion

The most important discovery of this study is that surgeon can safely and accurately put screws on the bone corridors around the

acetabulum with the assistance of the SVMN system. The case report demonstrates a new navigation method that assists difficult screws insertion in acetabulum during surgery. Acetabular anatomy is complex, and the surgical exposure is small, therefore, it is necessary to accurately design the screw trajectory in the preoperative screw view mode, and then implant the guide wire according to the safely designed trajectory. SVMN displays a perfect screw position on the static axial, sagittal, and coronal image of CT, and the fracture morphology and the navigation of the guide wire's direction in the small bony periacetabular corridors can be clearly seen through the image. The relative position of the patient's tracker and surgical tools must be maintained during surgery,^[17] otherwise the operation will fail. As a result, perfect preoperative surgical design and steady intraoperative navigational image are the key points of the whole operation.

ORIF for the treatment of acetabular anterior column fractures are usually done by ilioinguinal approach and the posterior approach usually uses the classic K-L approach.^[18] The advantages of ilioinguinal approach^[19] are small interference in muscle, less injury, concealed incision, faster recovery after internal fixation, and low incidence of heterotopic ossification. However, since the ilioinguinal approach passes through many

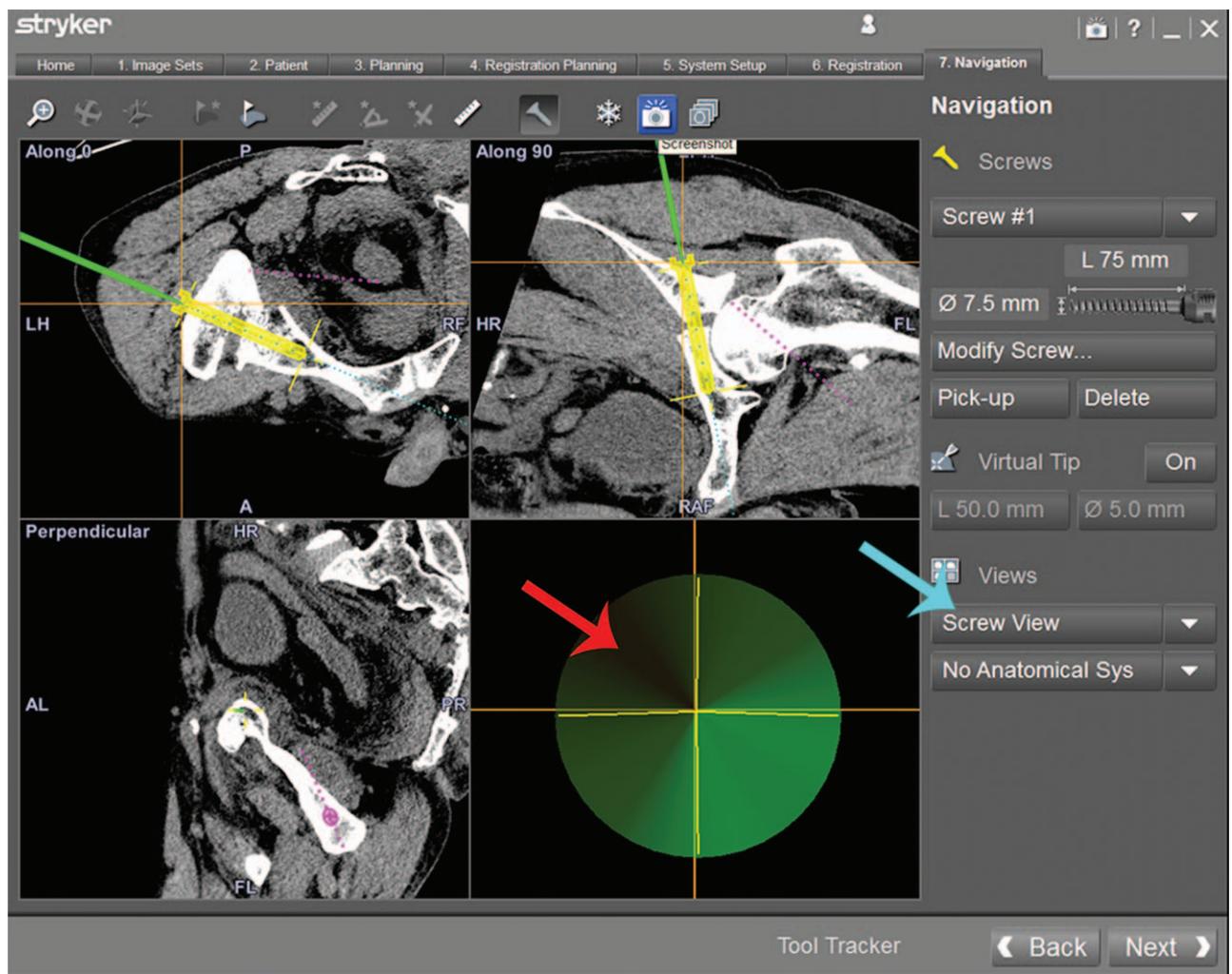


Figure 4. The screw view mode (blue arrow) of navigation was selected at workstation. When the right lower corner of the image shows green (red arrow), and it would be the best time to implant a guide wire.

important tissues, and the anatomic level is complex, ORIF still leads to various complications, such as the injury of spermatic cord^[20] or the circular ligament of the uterus, and the injury of the femoral nerve^[21] and the lateral femoral cutaneous nerve,^[22] which consequently may cause the dysfunction of the lower extremities, and the hypesthesia of the anterolateral thigh skin. What's more, vascular damage to the femur can lead to severe intraoperative bleeding,^[3] even shock and death, so particular attention should be paid to the communicating branches between the external iliac artery^[23–25] and inferior epigastric artery, which is called “death crown”, and its injury may cause fatal bleeding. The posterior approach of the acetabulum is restricted by the superior gluteal vessels and nerves, and the scope of exposure is limited as well. The sciatic nerve, the medial circumflex artery and the superior gluteal vessels may be damaged during the operation.^[4] In addition, ORIF may cause another problem that is the infection of the incision.^[6,7] Although the incidence of deep incision infection is low, superficial infection is very common, especially in obese or diabetic patients, and is one of the main causes of incisional hernia.^[26,27] The purpose of the treatment of acetabular fractures is to reconstruct the integrity of the articular surface, but it is also important to avoid or reduce the incidence of

complications, and this would be a challenge to the less experienced surgeons. We solved this problem perfectly using the navigation screw view mode.

PPS implantation is particularly challenging due to its complex 3D anatomy. A clinical study reported the malposition rate of PPS implantation under fluoroscopy guidance was as high as 16.7%.^[28] In our study, the accuracy rate of screw position as grade 0 was 100%. We attribute this positive result to the application of the navigation system for preoperative planning and the guidance of pedicle screw insertion with SVMN.

In our study, the implanting time of 2 screws was 45.5 minutes including image acquisition, surgical design, guide wire insertion, and screw implantation, and it took 6.7 minutes for the 2 guide wires to be implanted. Under screw view mode of navigation, the numbers of guide wire attempts were reduced, and each screw was successfully inserted at its first attempt. Research suggests that navigation systems did not require additional operation time for setup of the navigation devices.^[29] Besides that, study illuminated that using navigation guidance result in significantly shorter fluoroscopic time than fluoroscopic guidance does for checking the position of the guide wire.^[30] We consider these positive results are related to the application of SVMN.

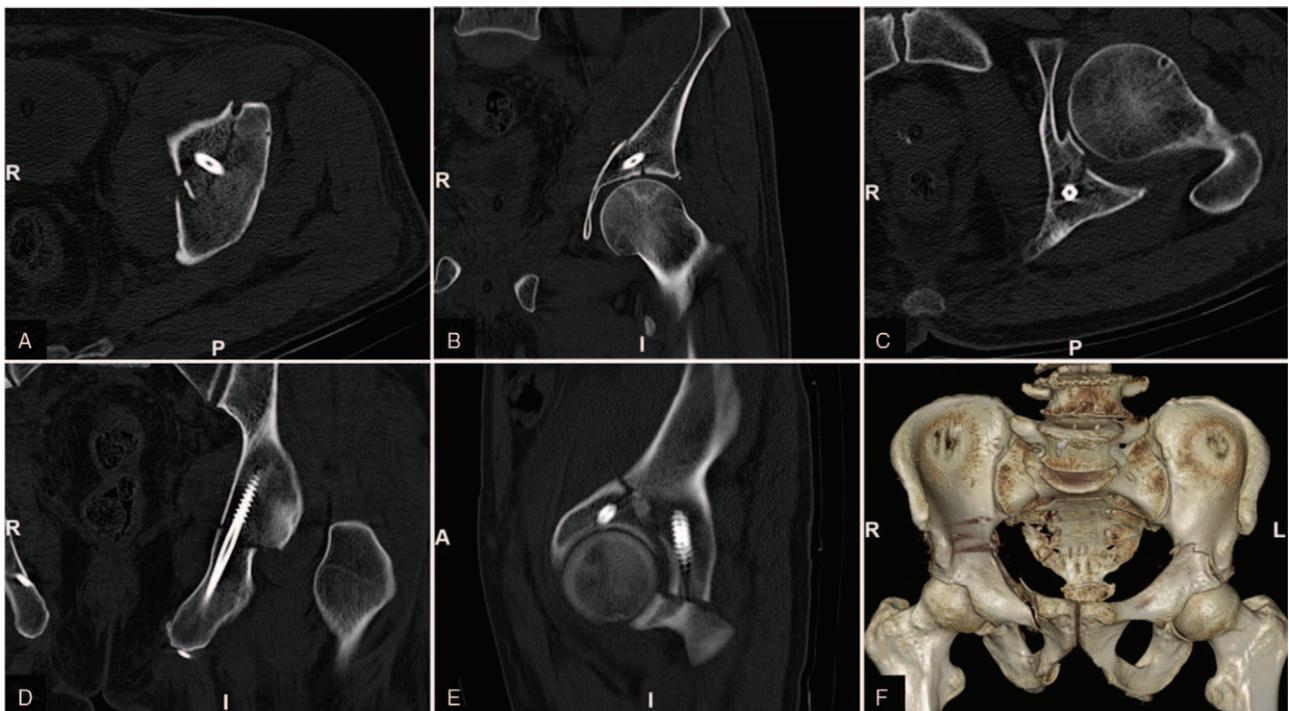


Figure 5. Postoperative 3D CT examination of pelvis. (A) The axial plane of anterior acetabular column indicated that the displacement gap of fracture was improved to 0.5 mm, (B) The coronal plane of anterior acetabular column indicated that the displacement gap of fracture and step were significantly improved to 0.6 and 0 mm, (C) The axial plane of posterior acetabular column showed that the displacement gap of fracture and step were significantly improved to 1.3 and 0.3 mm, (D) The coronal plane of posterior acetabular column showed that the displacement gap of fracture and step were significantly improved to 1.4 and 0 mm, (E) The sagittal plane of acetabular fracture showed that the screws were on the outside of the articular surface and fracture fixation was good, (F) The 3D reconstruction image of pelvis. 3D=3 dimensional, CT=computed tomography.

Regarding fracture dislocations, the fracture dislocation of anterior/posterior column on axial image was 9.8/7.8 mm preoperatively and 0.5/1.3 mm postoperatively, that on sagittal image was 6.4/3.7 mm before surgery and 1.3/1.4 mm postoperatively, and that on coronal image was 8.0/7.3 mm before surgery and 0.6/1.4 mm postoperative. Schwabe P et al^[16] reported that the mean fracture displacement of gap reduced from 4.1 ± 1.8 mm to 0.4 ± 0.7 mm, and the mean fracture displacement of step reduced from 1.4 ± 0.6 mm to 0.2 ± 0.4 mm. Our reduction results were similar to those of the literature reported.^[16] In our study, there were small steps postoperative, however, fractures achieved bony union and the hip joint functioned normally at the end of the follow-up. We attribute these positive results to the precise screw implantation with SVMN thus the fracture region achieved stable fixation and facilitated bony union.

Many authors reported excellent results of PPS fixation for stabilizing the acetabulum fracture. However, screw loosening is a typical complication of the acetabulum fracture, which may be related to osteoporosis.^[30,31] Its prevention is crucial, as it has been associated with the occurrence of several complications, including screw breakage and insufficient strength of biomechanics. In our case, no periacetabular screw loosening was observed, either because of the short time of follow-up or because SVMN was used to complete the correct screw implantation. Furthermore, implanting all PPS in 1 time avoided multiple drill holes that may lead to screw loosening.

Several drawbacks of this review are summarized as follow. First, the surgeon needs to be quite familiar with the state of navigation, and constantly judge whether the image is drifted in the navigation during the operation, thus to avoid the operation

Table 2
The fracture displacement of gap and step on axial, coronal, and sagittal plane of CT image.

FD	Axial		Coronal		Sagittal	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
GAC, mm	9.8	0.5	8.0	0.6	6.4	1.3
SAC, mm	—	—	0.2	0	1.9	0.9
GPC, mm	7.8	1.3	7.3	1.4	3.7	1.4
SPC, mm	0.2	0.3	2.9	0	1.8	1.5

CT=computed tomography, FD=fracture dislocation, GAC=gap of anterior column, GPC=gap of posterior column, mm=millimeter, Post-=postoperative, Pre-=preoperative, SAC=step of anterior column, SPC=step of posterior column.

failure of the operation due to the deviation of navigation accuracy. Secondly, the range of indications is narrower, and it is only suitable for minimal dislocation of acetabular fractures.

In conclusion, the PPS insertion assisted by SVMN system is a simple and highly feasible procedure for less-experienced surgeons. Our lesson is that the relative position between the acetabular and the patient tracker must be static to ensure the accuracy of the entire system throughout the operation.

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References

- [1] Kanda A, Kaneko K, Obayashi O, et al. Treatment of postoperative sciatic nerve palsy after total hip arthroplasty for postoperative acetabular fracture: a case report. *Ann Med Surg (Lond)* 2016;11:39–41.
- [2] Chaus GW, Heng M, Smith RM. Occult internal iliac arterial injury identified during open reduction internal fixation of an acetabular fracture: a report of two cases. *Injury* 2015;46:1417–22.
- [3] Gaheer RS, Rysavy M, Al Khayarin MM, et al. Femoral artery intimal injury following open reduction of an acetabular fracture. *Orthopedics* 2009;32:212.
- [4] Haidukewych GJ, Scaduto J, Herscovici DJr, et al. Iatrogenic nerve injury in acetabular fracture surgery: a comparison of monitored and unmonitored procedures. *J Orthop Trauma* 2002;16:297–301.
- [5] Fassler PR, Swiontkowski MF, Kilroy AW, et al. Injury of the sciatic nerve associated with acetabular fracture. *J Bone Joint Surg Am* 1993;75:1157–66.
- [6] KV K, DM M, BS S, et al. Avascular necrosis of acetabulum: the hidden culprit of resistant deep wound infection and failed fixation of fracture acetabulum—a case report. *J Orthop Case Rep* 2015;5:36–9.
- [7] Eckardt H, Lind D, Toendevold E. Open reduction and internal fixation aided by intraoperative 3-dimensional imaging improved the articular reduction in 72 displaced acetabular fractures. *Acta Orthop* 2015;86:684–9.
- [8] Johnson-Vaught LD. Comminuted pelvic fracture with retroperitoneal bleed in a geriatric patient: a case study. *Adv Emerg Nurs J* 2013;35:192–206.
- [9] de Ruiter GC, Jellema K, van de Kallen BF, et al. Peroneal nerve injury due to heterotopic ossification: rare complication following surgical treatment of an acetabular fracture. *Ned Tijdschr Geneesk* 2015;160:A9644.
- [10] Bosse MJ, Poka A, Reinert CM, et al. Heterotopic ossification as a complication of acetabular fracture. Prophylaxis with low-dose irradiation. *J Bone Joint Surg Am* 1988;70:1231–7.
- [11] Kaempffe FA, Bone LB, Border JR. Open reduction and internal fixation of acetabular fractures: heterotopic ossification and other complications of treatment. *J Orthop Trauma* 1991;5:439–45.
- [12] Caviglia H, Mejail A, Landro ME, et al. Percutaneous fixation of acetabular fractures. *EFORT Open Rev* 2018;3:326–34.
- [13] Xu P, Wang H, Liu ZY, et al. An evaluation of three-dimensional image-guided technologies in percutaneous pelvic and acetabular lag screw placement. *J Surg Res* 2013;185:338–46.
- [14] Yu T, Wang Y, Zhang XW, et al. Multimodal intraoperative monitoring during reduction of spine burst fracture and dislocation prevents neurologic injury. *Medicine (Baltimore)* 2018;97:e0066.
- [15] Smith HE, Yuan PS, Sasso R, et al. An evaluation of image-guided technologies in the placement of percutaneous iliosacral screws. *Spine (Phila Pa 1976)* 2006;31:234–8.
- [16] Schwabe P, Altintas B, Schaser KD, et al. Three-dimensional fluoroscopy-navigated percutaneous screw fixation of acetabular fractures. *J Orthop Trauma* 2014;28:700–6.
- [17] Chui KH, Chan CCD, Ip KC, et al. Three-dimensional navigation-guided percutaneous screw fixation for nondisplaced and displaced pelvis-acetabular fractures in a major trauma centre. *Int Orthop* 2018;42:1387–95.
- [18] Matta JM. Fractures of the acetabulum: accuracy of reduction and clinical results in patients managed operatively within three weeks after the injury. *J Bone Joint Surg Am* 1996;78:1632–45.
- [19] Karkare N, Yeasting RA, Ebraheim NA, et al. Anatomical considerations of the internal iliac artery in association with the ilioinguinal approach for anterior acetabular fracture fixation. *Arch Orthop Trauma Surg* 2011;131:235–9.
- [20] Firoozabadi R, Stafford P, Routt M. Risk of spermatic cord injury during anterior pelvic ring and acetabular surgery: an anatomical study. *Arch Bone Jt Surg* 2015;3:269–73.
- [21] Gruson KI, Moed BR. Injury of the femoral nerve associated with acetabular fracture. *J Bone Joint Surg Am* 2003;85-A:428–31.
- [22] Reinhold W, Schroeder AD, Schroeder M, et al. Retroperitoneal anatomy of the iliohypogastric, ilioinguinal, genitofemoral, and lateral femoral cutaneous nerve: consequences for prevention and treatment of chronic inguinodynia. *Hernia* 2015;19:539–48.
- [23] Koelling E, Mukherjee D. Extrinsic compression of the external iliac artery following internal fixation of an acetabular fracture. *J Vasc Surg* 2011;54:219–21.
- [24] Langford JR, Trokhan S, Strauss E. External iliac artery thrombosis after open reduction of an acetabular fracture: a case report. *J Orthop Trauma* 2008;22:59–62.
- [25] Klos K, Marintschev I, Bottcher J, et al. External iliac artery thrombosis associated with the ilio-inguinal approach in the management of acetabular fractures: a case report. *J Med Case Rep* 2008;2:4.
- [26] Deitel M, Alhindawi R, Yamen M, et al. Dexon plus versus Maxon fascial closure in morbid obesity: a prospective randomized comparison. *Can J Surg* 1990;33:302–4.
- [27] Pollock AV, Evans M. Early prediction of late incisional hernias. *Br J Surg* 1989;76:953–4.
- [28] He JL, Tan GQ, Zhou DS, et al. Comparison of isocentric C-arm 3-dimensional navigation and conventional fluoroscopy for percutaneous retrograde screwing for anterior column fracture of acetabulum an observational study. *Medicine* 2016;95.
- [29] Wang JQ, Wang Y, Feng Y, et al. Percutaneous sacroiliac screw placement: a prospective randomized comparison of robot-assisted navigation procedures with a conventional technique. *Chin Med J (Engl)* 2017;130:2527–34.
- [30] Ohtori S, Inoue G, Orita S, et al. Comparison of teriparatide and bisphosphonate treatment to reduce pedicle screw loosening after lumbar spinal fusion surgery in postmenopausal women with osteoporosis from a bone quality perspective. *Spine* 2013;38:E487–492.
- [31] Muller F, Fuchtmeyer B. Percutaneous cement-augmented screw fixation of bilateral osteoporotic sacral fracture. *Der Unfallchirurg* 2013;116:950–4.