CT (ISO-C-3D) image based computer assisted navigation in trauma surgery: A preliminary report

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Introduction: CT (ISO-C-3D) image based navigation has recently been introduced to improve the image quality and accuracy during computer assisted orthopaedic surgeries. We report on our early experience using this novel technique in intra-articular lower extremity fracture management.

Methods: Real time CT-based navigation assisted surgery was used in the treatment of five patients with fractures of tibial plateau (3), talus (1) and acetabulum (1). The mean age was 38 years (range, 29–47). Feasibility, pitfalls and adequacy of reduction and fixation were evaluated. Additional time spent before the surgical incision (Δt) using the ISO-C navigation and total operative time was measured.

Results: All five procedures were regarded as technically successful. Accurate reduction and fixation of all the fractures was achieved. All the fractures were fixed with closed reduction and internal cannulated screw fixation. Mean additional time spent after the start of anaesthesia and until surgical incision for cannulated screw insertion (Δt) was 26 min. The average total operative time was 109 min.

Conclusion: Combining the ISO-C-3D images with computer navigation can improve the safety and decrease the invasiveness of the procedures in trauma surgery. 3D navigation makes the reduction and screw placement highly accurate but may extend the operative time.

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Summary

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Introduction

Computer assisted technology brings important digitised information into the operating room, enabling the accomplishment of two main goals: minimal invasive surgery and maximal accuracy. Moreover, both surgeon and patient enjoy a significant
reduction in the amount of radiation exposure usually associated with orthopaedic trauma surgery.\(^8\) In principle, there are two imaging modalities available for navigation: fluoroscopy and computed tomography (CT). Navigation was first used in spinal surgery for implantation of pedicle screws.\(^6,7\) Its use has expanded to include general orthopaedic trauma. Fluoroscopic based navigation provides real time 2D imaging and is most commonly used in orthopaedic trauma surgery.\(^9\) CT-based navigation is performed using preoperative acquired CT images which are then uploaded to the navigation workstation and adapted to the actual intraoperative anatomical site with a registration procedure. This technique does not provide real time 3D CT visualization and has the disadvantage of increased time and may not be practical when there is relative change in position between fracture fragments.\(^2\)

Three-dimensional fluoroscopy using a mobile isocentric C-arm with 3D imaging (SIREMOBIL ISO-C-3D\(^{TM}\), Siemens AG, Germany) is a new imaging modality that allows the acquisition of CT-like images during surgery. This device can be combined with computerised navigation unit to perform 3D image based navigation without the need of preoperative processing and registration.\(^1\) To date, very few studies have described the use of this technique in fracture fixation.\(^10,11\)

We report five patients with intra-articular fractures treated surgically by using CT (ISO-C-3D) image based computer assisted navigation (ISO-C-Navigation). Our primary purpose was to evaluate the feasibility and advantages of using the ISO-C-Navigation in fixation of intra-articular fractures with percutaneous cannulated screws. A secondary objective was to measure the operative time implications while using this technique.

**Patients and methods**

Between June 2005 and January 2006, ISO-C-Navigation was used for fracture fixation in five patients at our institution. IRB approval and informed consent from each patient for surgical treatment were obtained. The patients were between the ages of 28 and 57 (mean age, 40 years). Three patients were male, and two were female (Table 1). Pre-operative X-rays (all patients) and regular spiral computed tomography (CT) scanning (three patients) were used for fracture diagnosis and evaluation. All the fractures were intra-articular and involved the lower extremity: tibial plateau AO Type 41-B1 (3), neck of talus Hawkins Type-I (1) and acetabulum posterior column AO Type 62-A2 (1).

### Principle and technique

During the operation, ISO-C-3D\(^{TM}\) can be utilized both as a regular fluoroscopic device and also as a CT-like image producer. Firstly, percutaneous fracture reduction maneuvers are performed under fluoroscopy guidance. Then a reference guide, which will function as a link to transfer CT-like image data from ISO-C to the navigation unit, is inserted into bone tissue close to fracture site. At this stage, the ISO-C scan of the fracture (max. scan volume 12 cm\(^3\)) is obtained and the image data is exported to the navigation unit already in a registered form. Following this, as in conventional fluoroscopy based navigation, tracked reference frame is connected to the surgical instrument and the signals from this tracker are integrated with the CT images of ISO-C. After the virtual image of the fixation tool is obtained, the surgical incision is done to proceed to the CT (ISO-C-3D) image based computer assisted cannulated screw insertion for fracture fixation. The navigated CT images are updated in real time by the computer as the tracked instruments and anatomy move throughout the operation (Fig. 1(1)—(5)).

The operations were accepted as technically successful if ISO-C could be combined with the navigation unit to perform real time CT (ISO-C-3D) image based computer assisted surgery. Clinical success was defined as the satisfactory reduction and fixation of the fracture. We defined the additional time spent before starting the operation for using the ISO-C-Navigation (\(\Delta\) time) as the time passed between the insertion of the reference guide and until the surgical incision. This period included the ISO-C scan acquisition, image evaluation, combination of the images with the navigation unit and registration of surgical tools to start performing ISO-C-Navigation.

<table>
<thead>
<tr>
<th>Case</th>
<th>Age-sex</th>
<th>Fracture type</th>
<th>Total operative time (min)</th>
<th>(\Delta) time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36 M</td>
<td>Lt acetabulum AO 62-A2</td>
<td>160</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>44 F</td>
<td>Rt tibial plateau AO 41-B1</td>
<td>123</td>
<td>48</td>
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<tr>
<td>3</td>
<td>47 M</td>
<td>Rt tibial plateau AO 41-B1</td>
<td>75</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>29 F</td>
<td>Lt tibial plateau AO 41-B1</td>
<td>80</td>
<td>18</td>
</tr>
<tr>
<td>5</td>
<td>34 M</td>
<td>Rt talus neck Hawkins 1</td>
<td>107</td>
<td>32</td>
</tr>
</tbody>
</table>
Results

Case 1

Thirty-six-year-old male, fell from height of three meters and sustained a fracture of left acetabulum and left olecranon. Regular CT scan was performed pre-operatively which revealed a fracture of left acetabulum posterior column AO Type 62-A2 with congruent joint surface. The patient underwent closed reduction and internal fixation of the fracture with two cannulated screws that were inserted using ISO-C-Navigation (Fig. 2). The olecranon fracture was non-displaced and treated conservatively. This patient stayed at the hospital for 5 days post-operatively.

Case 2

Forty-four-year-old female, was a pedestrian involved in a motor vehicle accident and injured her right knee. Pre-operative imaging was limited to
regular X-rays and showed fractures of right tibial plateau AO Type 41-B1 and right tibial eminence Mc Keever Type 1 together with avulsion of right medial collateral ligament. The patient underwent closed reduction and internal fixation with two laterally inserted cannulated screws by using the ISO-C-Navigation (Fig. 1(1–5)). She was discharged from the hospital at post-operative day 5.

Case 3

Forty-seven-year-old male, sustained an isolated fracture of his right tibial plateau after falling from a flight of stairs. Pre-operative X-rays revealed AO Type 41-B1 fracture of right tibial plateau which was fixed with two cannulated screws using the ISO-C-Navigation. The patient was discharged from the hospital 2 days after the surgery.

Case 4

Twenty-nine-year-old female, was a passenger in a train accident and received trauma to her left lower extremity. She had fractures of left femur, left tibial plateau and degloving of the left thigh. The patient underwent fixation of the femur fracture and soft tissue debridement on her arrival to hospital. A regular CT scan was performed before the operation and left tibial plateau AO Type 41-B1 fracture was treated surgically with closed reduction and internal fixation. Two cannulated titanium screws were inserted with use of ISO-C-Navigation. Two days after this operation, she was transferred to treatment and follow-up by department of plastic surgery.

Case 5

Thirty-four-year-old male, involved in a motor vehicle accident as a passenger and had an isolated fracture of right foot talar neck Hawkins Type-1. Closed reduction and internal fixation with one cannulated screw was performed with ISO-C-Navigation guidance. The patient had no preoperative regular CT scan. His post-operative hospital stay was 2 days.

In all five procedures, Siremobile (ISO-C-3D) could be combined with navigation unit and ISO-C-Navigation was successfully performed in cannulated screw fixation of intra-articular fractures. The operating team was satisfied with accuracy of the reduction and fixation of all the fractures. Blood loss was unremarkable in all the surgeries. No intra or post-operative complications were reported. Average post-operative stay at the hospital was 3 days. Mean additional time (Δ time) spent after the start of anaesthesia and until surgical incision was 26 min. The average total operative time passed between surgical incision and skin closure was 109 min (Table 1).

Discussion

Our initial experience with ISO-C-3D in combination with computer assisted surgery has been very encouraging. ISO-C-Navigation brings the advantage of performing computer assisted surgery in a three dimensional image background as opposed to 2D visualization. Logistically it is similar to a regular C arm used for 2D imaging, yet it provides real time intraoperative CT-like images that can be transferred to the navigation unit directly. Although the images obtained by ISO-C are of reduced quality compared to regular CT scanning, this is not significant in reduction and fracture evaluation. Further advances in this imaging for use intraoperatively are being developed, such as cone beam CT, which will provide better soft tissue resolution.
At present, the scan volume is limited to 12 cm³ and for this reason there are difficulties in performing navigation assisted surgeries involving larger bony regions with ISO-C image guidance. The current use of ISO-C-Navigation is primarily in closed or mini-open fixation of intra-articular fractures. We have shown that the visualization of the articular surface with ISO-C-Navigation is most satisfactory and have performed accurate reductions and fixation using cannulated screws in the talus, tibial plateau and acetabulum. Computer assisted percutaneous screw fixation under CT-like image guidance is of valuable help in understanding the fracture morphology and aiming the screws accordingly. This technique may further decrease the need for open or arthroscopy assisted surgeries.³

The average extra time ($\Delta$ time) of 26 min required before surgical incision for ISO-C navigation assisted screw insertion is not negligible. When retrospectively looking at the procedures performed at our institution by the same team, average $\Delta$ time added during fixation of fractures using 2D navigation was found to be 14 min. However, none of the treating surgeons considered this an obstacle to its use, particularly given the superior imaging in the talus and acetabulum. Comparison to no navigation surgeries is not practical as these mandate more open procedures with their inherent disadvantage. Furthermore, the time spent to perform surgeries using ISO-C-3D CT image based navigation will likely decrease as there is increased familiarity by the operative team as a whole.

In summary, we have shown this technique to be most viable and worthy of continued study and application. The advantages of navigation in permitting fracture reduction and fixation to be performed in a closed or minimally open technique are clearly beneficial. The ability to provide real time 3D imaging in combination with this will further improve our ability to provide optimal outcomes for our patients.

References