Secure paediatric pelvic fracture external fixation using an intraoperative support device

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SUMMARY
Secure fixation by inserting a half-pin into the iliac crest as a pelvic external fixator is important. However, the thickness of the iliac bone depends on its location and this makes it difficult to insert a half-pin accurately. The iliac crest is especially narrow in the paediatric pelvis, making it difficult to insert the half-pin accurately compared with an adult pelvis. A case of pelvic external fixation is described for a paediatric pelvic fracture in this report, in which preoperative planning for half-pin insertion was performed accurately using a preoperative three-dimensional CT based on an intraoperative support device that uses the functional pelvic plane as a reference.

BACKGROUND
The acute treatment of a pelvic ring fracture using external fixation was necessary for pelvic stabilisation.1 The common methods of external fixation for pelvic fracture were the high-route method and the subcristal method;2 insert bilateral iliac crest, or low-route method; and insert bilateral anteroinferior iliac spine.3 The high-route method is widely used because this technique is easy and fast, and does not require fluoroscopic equipment. Sitting position with hip flexion was interfered with external fixators, and risk of lateral femoral cutaneous nerve injury could be increased on subcristal external fixators, and risk of lateral femoral cutaneous nerve injury could be increased on subcristal external fixators.4 The high-route method is widely used because this technique is easy and fast, and does not require fluoroscopic equipment. Sitting position with hip flexion was interfered with external fixators, and risk of lateral femoral cutaneous nerve injury could be increased on subcristal external fixators.4

FIGURE 2 Initial CT shows bilateral sacrum, right pubic, sciatic bone fracture and pubic symphysis disruption.

CASE PRESENTATION
A boy in early adolescence fell down from the sixth floor and was injured. He was taken to our hospital in an ambulance. His height was 152.8 cm, weight was 33.6 kg and body mass index was 14.4. A pan CT scan was performed after tracheal intubation and sheet wrapping. The diagnoses were traumatic subarachnoid haemorrhage, bilateral traumatic pneumothorax, retroperitoneal haematoma and pelvic fracture (bilateral sacrum, right pubic, sciatic bone fracture and pubic symphysis disruption) (figures 1 and 2). Pelvic fracture was classified as 61B2.3 according to AO classification9 and type IV according to Torode and Zieg classification.10 External fixation for the pelvic fracture was planned after chest tube insertion and Interventional Radiology (IVR) for retroperitoneal haematoma. The route of half-pin insertion was evaluated using initial CT data. The CT data were analysed with 3D template software (ZedHip®, Lexi Corp, Tokyo, Japan), which can reconstruct multiple planes. The 3D pelvic coordinates were evaluated using initial CT data. The CT data were analysed with 3D template software (ZedHip®, Lexi Corp, Tokyo, Japan), which can reconstruct multiple planes. The 3D pelvic coordinates were evaluated using initial CT data. The CT data were analysed with 3D template software (ZedHip®, Lexi Corp, Tokyo, Japan), which can reconstruct multiple planes. The 3D pelvic coordinates were evaluated using initial CT data.
defined with a plane passing through the bilateral anterior superior iliac spine (ASIS) and parallel to the CT scan table, with an FPP. Pin insertionplans were performed as follows: first, a point A was 15 mm proximal to the ASIS and a point B was 30 mm proximal to the ASIS. A plane from each point to the sciatic notch was created (figure 3A). The length of the half-pin within the iliac bone was planned at 50 mm, based on the thread length of a half-pin of 50 mm. Preoperative planning confirmed that a pin depth of 50 mm into the iliac bone would not reach the hip joint. The route of half-pin insertion from each point was made. Radiographic inclination (RI) and radiographic anteversion (RA) of each point were calculated using similar methods to the cup placement angle calculation for total hip arthroplasty (THA) (figure 3B). RI was 118°, RA was 31° on the right point A; RI was 125°, RA was 24° on the right point B; RI was 122°, RA was 37° on the left point A; and RI was 128°, RA was 31° on the left point B (C).

Figure 3 Preoperative planning using three-dimensional template software. Point A was located at 15 mm proximal to anterior superior iliac spine (ASIS), point B was located at 30 mm proximal to the ASIS (A). The route of half-pin insertion from each point was made. Radiographic inclination (RI) and radiographic anteversion (RA) of each point were calculated using similar methods to the cup placement angle calculation for total hip arthroplasty (B). Each half-pin angle was calculated. RI was 118°, RA was 31° on the right point A; RI was 125°, RA was 24° on the right point B; RI was 122°, RA was 37° on the left point A; and RI was 128°, RA was 31° on the left point B (C).

Figure 4 The 2.0 mm Kirschner wires were inserted into the bilateral anterior superior iliac spine (ASIS), and point A (15 mm proximal to the ASIS) and point B (30 mm proximal to the ASIS) were marked by a skin marker (A). The intraoperative support device mounts on the bilateral ASIS creating a functional pelvic plane and navigates the angle of half-pin insertion (B). Each half-pin angle was inputted into the angle guide, and half-pins with a diameter of 4 mm were inserted on both sides from points A and B parallel to the indicator (C).

RA was 24° on the right point B; RI was 122°, RA was 37° on the left point A; and RI was 128°, RA was 31° on the left point B (figure 3C).

TREATMENT
The pelvic instability and pubic symphysis disruption were observed using a fluoroscope under general anaesthesia. The patient was placed in the supine position and 2.0 mm Kirschner
wires (K-wires) were inserted into the ASIS bilaterally. A point of 15 mm proximal to the ASIS and a point of 30 mm proximal to the ASIS were marked by a skin marker (figure 4A). A skin incision at each point was made. The intraoperative support device was mounted on the bilateral ASIS through the inserted K-wires. This device creates FPP and navigates the angles of half-pi insertion (figure 4B). The angle of each half-pin was inputted into the angle guide, and half-pins from points A and B parallel to the indicator with a diameter of 4.0 mm were inserted on both sides (figure 4C). We did not use fluoroscopy during half-pi insertion; however, an outlet view or an outlet-obturador view tilted to a closed obturator foramen oblique image can be helpful during pin insertion using fluoroscopy.11 After half-pin insertion, we checked to ensure the half-pin had been accurately inserted into the iliac bone using fluoroscopy with rotation in the pin axis. We also checked to confirm that no penetration into the hip joint had occurred using fluoroscopy with rotation perpendicular to the half-pin axis. Subsequently, reduction of the pubic symphysis disruption was confirmed by fluoroscopy and secure external fixation was performed (Hoffmann II, Stryker Corp, Michigan, USA). There was no external fixation interference even at 90° of hip flexion postoperatively (figure 5). CT data were obtained after surgery and pin placement was evaluated. RI was 131°, RA was 35° on the right point A; RI was 128°, RA was 20° on the right point B; RI was 134°, RA was 40° on the left point A; RI was 126°, RA was 33° on the left point B (figure 6). The mean differences in the insertion angles of the four half-pins between preoperative and postoperative CT were 7.5° for RI and 3.3° for RA, respectively. The four half-pins were inserted into the iliac bone correctly without perforation. Secure fixation was seen on radiograph after surgery (figure 7).

OUTCOME AND FOLLOW-UP
The patient was allowed to sit on the bed and transfer to wheelchair on the day after surgery. Walking with partial weightbearing with a gait walker was permitted 8 weeks after surgery. External fixation was continued for 10 weeks, and after confirming that bone union had been achieved, it was removed (figure 8). Any pins that were secured in fixation were not loosen with pin removal. No complications such as infection, loosening, leg length discrepancy or nerve damage were observed. He could walk with a cane at 12 weeks after surgery and Japanese Orthopedic Association hip score12 was 100 points 4 months after surgery, that is, he could walk without a cane and had no pain.

DISCUSSION
Paediatric pelvic fractures are rare and commonly caused by high-energy trauma, such as falls from height or road traffic accidents.13 The pelvic fracture itself is often stable and treated conservatively, although it is often complicated by other traumatic injuries, such as thoracoabdominal injuries.14 However, surgical treatment is indicated for unstable paediatric fracture type.15 This case had multiple traumas including subarachnoid haemorrhage, bilateral traumatic pneumothorax, retroperitoneal haematoma and pelvic fracture, classified as 61B2.3 by the AO classification and type
The pelvic ring was additionally unstable under general anaesthesia. Therefore, external fixation was planned. Half-pin insertion was planned based on data obtained from the preoperative CT, and pelvic external fixation using an intraoperative support device that references on an FPP was performed. The 3D template software for preoperative planning of THA and cup placement was conventionally and accurately performed using an FPP-referenced surgical support device intraoperatively in our institution. The surgical support device based on 3D THA template was applied for this half-pin insertion. Nakasone et al reported a new external fixation half-pin route, which was located at the point averaging 12.3 mm dorsally from the iliac crest with a mean length of 92.7 mm. Half-pin routes were planned using the point of 15 mm proximal to the ASIS at a point of 30 mm proximal to the ASIS, respectively, with reference to their reports. In this case, the template cup was overlaid on each entry point of the iliac bone in each route after creating the four half-pin routes in the 3D template software. RI and RA half-pin route values against FPP were calculated automatically. The direction of half-pin insertion could be checked intraoperatively by inputting these values into a surgical support device for THA. This device was reported to be accurate within 3° for cup placement. The mean difference in pin insertion angle between preoperative and postoperative CT was 7.5° for RI and 3.3° for RA in this case. We have to consider that the reduction procedure affected this result, although the mean RI difference was greater than the result of the study reported by Nakasone et al. This could be considered a reduction angle from a different perspective, since the postoperative CT showed that the half-pins were placed into the iliac bone and there was no perforation. This procedure’s advantage is that if the preoperative planning is accurate and the procedure is performed according to the preoperative plan, there is no need to use fluoroscopic equipment during surgery. This procedure enables hip joint flexion of more than 90° and use of wheelchair easily with external fixation, although the low-route method often interferes hip flexion. The time required for surgical planning and the complicated procedure are the disadvantages. However, this technique is useful for high-route external fixation because it allows the insertion of a long half-pin into the bone. In this case, bone fusion was achieved without loosening. This technique may be useful in paediatric pelvic fractures since the iliac bone is narrow in children and external fixation is often used in the treatment of pelvic fractures for a prolonged period. Wide-scale long-term research is needed to assess the safety and effectiveness of this procedure.

This report has some limitations. This is a single, unique case report. It is necessary to perform cases to prove its usefulness since this is a case report using development of an intraoperative support device. Open reduction and internal fixation was often chosen for type C, although this procedure is difficult to perform in unstable pelvic fractures with AO classification type C. In addition, we consider that the reduction of pelvic fractures may affect the accuracy of the procedure because the position of the pelvis in the FPP is different preoperatively and postoperatively. Preoperative planning was performed using CT data already obtained in

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**Patient's perspective**

I could not move at all because of the pain in my back and pelvis when I was taken to the hospital. The time it took to get into the operating room was so painful that I thought it was out of this world. An external fixation was set up in front of my abdomen after the surgery, but the pelvic pain was completely gone. The next day, the doctor allowed me to raise the bed to 90°, and also allowed me to move to a wheelchair. The nurse checked the wound of the iliac pins and it did not get infected. I had no pain. I was told that my progress was good, so I trained to walk with a walker with partial weightbearing starting at 8 weeks postoperatively. External fixation was removed at 10 weeks postoperatively, but the pain did not increase after that. I am now able to walk without any aids, and I am satisfied with the results. The doctor told me that it was a very serious fracture and could have required major surgery. I was told that the pelvis is an important part of the body that not only protects the organs but also transmits power to walk. I am very grateful that he was able to heal my pelvic fracture by simply fixing it with external pins. At first I was afraid to look at the pins, I gradually forgot they were there since there was no pain and they were only applying gauze. I also thought the external fixation was a big device at first, but it was not as annoying as I thought it would be. Moreover, I was able to use a tablet computer and take remote classes. I was very relieved to hear that the strong external wound fixation saved me from a major surgery.

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**Learning points**

- This case report described one of the high-route methods for external fixation in paediatric pelvic fracture.
- Preoperative planning and using an intraoperative support device enable us to insert half-pins accurately without fluoroscopic equipment.
- This method may be useful because the fixation is secure and does not interfere with hip flexion that enables early mobilisation.
the emergency room to determine the route and length of the four pins in approximately 30 min. However, the time required for planning makes this technique more challenging in cases of pelvic fracture that involve massive haemorrhage.

CONCLUSION
Bone union was achieved without complications including infection and nerve injury, using an intraoperative support device that references the FFP, external fixation for paediatric pelvic fracture safe and secure.

Contributors TI, SN, MO and KN contributed equally to this work. SN designed the study, TI, SN and MO collected and analysed the data. TI and SN wrote the manuscript, while all authors contributed to critical revision for important intellectual content. KN contributed to overall supervision, but all authors provided approval for publication. All authors have made important intellectual contributions and have seen and approved the manuscript for submission.

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Case reports provide a valuable learning resource for the scientific community and can indicate areas of interest for future research. They should not be used in isolation to guide treatment choices or public health policy.

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