

Curved periacetabular osteotomy using intraoperative real-time 3-dimensional computed tomography with a robotic C-arm system

A case report

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Abstract

Rationale: Curved periacetabular osteotomy (CPO) is a procedure with excellent surgical outcome that has been proposed for patients with development dysplasia of the hip (DDH). However, the surgical outcomes depend on the surgeon's experience and proficiency.

Patient concerns: A 38-year-old female indicated she was experiencing left hip pain while walking.

Diagnoses: The patient was diagnosed with early-stage hip osteoarthritis due to DDH.

Interventions: The patient underwent CPO while a 3-dimensional flat-panel C-arm (Artis zeego; Siemens Healthcare, Forchheim, Germany) was used to confirm the real-time 3-dimensional computed tomography (CT) images during surgery. It was possible to confirm the accurate osteotomy curve using CT images twice during surgery: at the time of the ischial osteotomy and the quadrilateral surface osteotomy.

Outcomes: An ideal C-shaped osteotomy line was created as shown on the postoperative CT images. In addition, neither posterior column fracture nor intra-articular osteotomy was confirmed.

Lessons: The CPO using Artis zeego resulted in a satisfactory outcome, and this is the 1st report in the world to discuss the benefits of Artis zeego in pelvic osteotomy.

Abbreviations: AHI = acetabular head index, ARO angle = acetabular roof obliquity angle, CE angle = center edge angle, CPO = curved periacetabular osteotomy, 3D-CT = 3-dimensional computed tomography, DDH = development dysplasia of the hip, mGy = milligray, OR = operation room, PAO = periacetabular osteotomy.

Keywords: Artis zeego, curved periacetabular osteotomy, real-time 3-dimensional computed tomography

1. Introduction

The 3-dimensional (3D) flat-panel C-arm (Artis zeego; Siemens Healthcare, Forchheim, Germany) (Fig. 1) is a robotic C-arm system with multiaxis joints with 8 wheels which was originally developed as an interventional angiography imaging device for the cardiovascular field, and it enables flexible approaches to patients' imaging regions. Furthermore, it is a real-time 3-dimensional computed tomography (3D-CT) imaging device, which enables capturing of accurate 3D-CT images in a few seconds. There have been various applications and reports made within the cardiovascular field^{1,2} in the past. Recently, there have been several reports

of its intraoperative uses in surgery such as cerebral surgery where it is being placed in operation rooms along with a CT navigation system as a hybrid operation room (OR).^{3,4} There have also been reports of its usage in orthopedic fields, especially for spinal surgery for pedicle screw insertion accompanied by navigation^{5,6} as well as for ilio-sacral screw insertion during trauma surgery.⁷ By contrast, there have been several reports on various operative methods regarding pelvic osteotomy for patients with development dysplasia of the hip (DDH). However, in the present study the authors have performed curved periacetabular osteotomy (CPO), which was reported by Naito in 2005.⁸ CPO is a modified procedure of periacetabular osteotomy (PAO),⁹ where C-shaped osteotomy is performed through the medial side of the acetabulum and can be considered a safer and less invasive procedure compared to the other rotational acetabular osteotomies.¹⁰ However, the surgical outcomes depend on the surgeon's experience and proficiency. This study is the 1st in the world to discuss the benefits of Artis zeego in pelvic osteotomy and the use of Artis zeego for performing CPO during surgery while safely and accurately confirming the osteotomy line with real-time 3D-CT images.

2. Case report

This study was approved by the Institutional Review Board of Hyogo College of Medicine, and informed consent was obtained from the patient and her family.

Editor: N/A.

The authors report no conflicts of interest.

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Figure 1. (A) Illustration of the Artis zeego imaging system in the hybrid operation room. (B) Illustration of image capturing by the Artis zeego during surgery.

The patient is a 38-year-old female nurse. She started experiencing left hip pain during walking, which gradually worsened and led to difficulty working. She consulted our hospital for surgical purposes. However, range of motion limitations in the left hip was not confirmed, due to pain during walking. The modified Harris hip score was 81.4 points. Plain anteroposterior radiograph of the hip did not show the joint space narrowing with a sharp angle of 47° , a center edge (CE) angle of 14° , an acetabular roof obliquity (ARO) angle of 19° , and an acetabular head index (AHI) of 64%. She was diagnosed with grade 1 early stage hip osteoarthritis according to the Tönnis classification associated with DDH (Fig. 2). Surgical intervention via CPO was selected.

2.1. Operative procedure

Artis zeego was installed in a hybrid OR. After general anesthesia for the patient, the degrees of freedom of the C-arm was 1st



Figure 2. Anteroposterior radiograph of the hip with the 38-year-old female showing early stage hip osteoarthritis associated with development dysplasia of the hip in both hips.

confirmed with the patient in a supine position before surgery. A direct anterior approach with skin incision of approximately 8 cm was used for surgical exposure. The osteotomy was performed in the same manner according to Naito's method.^[8] The 1st real-time CT image was taken at the beginning of the osteotomy of the ischium when the ischium chisel was inserted at the ischium osteotomy region (Fig. 3A). The real-time CT image confirmed that the direction of the chisel was toward the infracotyloid groove and the osteotomy line had not reached the posterior column. After performing a pubic osteotomy, C-shaped osteotomy of the medial ilium was started using a curved chisel. The second real-time CT image was taken when the curved chisel reached the quadrilateral surface (Fig. 3B). The final stages of the osteotomy proceeded with the use of CT images to confirm that the direction of the osteotomy curve with the curved chisel was between the sciatic notch and the posterior line of the hip joint. The C-shaped osteotomy line could ultimately be connected with the ischium osteotomy line. After the osteotomy was performed, the acetabular fragment was rotated. The medicalization and adequate covering of femoral head were confirmed by the reoriented acetabular fragment using conventional fluoroscopic radiography. The reoriented acetabular fragment was fixed by four poly-L-lactic acid screws.

The total time of the surgery was 2 hours 11 minutes, and the amount of bleeding was 360 mL. The total radiation exposure level during operation was 321 miligray (mGy).

In the postoperative radiograph of the hip, the following improvements were confirmed: sharp angle of 30° , CE angle of 32° , ARO of 2° , and AHI of 81% (Fig. 4). An ideal C-shaped osteotomy line was created using postoperative CT and neither posterior column fracture nor intra-articular osteotomy was confirmed (Fig. 5). Bony fusion of the osteotomy site was complete at 6 months after surgery, and the modified Harris hip score improved to 95.7 points. The patient was able to return to work as a nurse.

3. Discussion

The CPO is a procedure that involves osteotomy from the medial side to the lateral side of the pelvis through a curve with a curved chisel. Compared to other rotational acetabular osteotomies, it

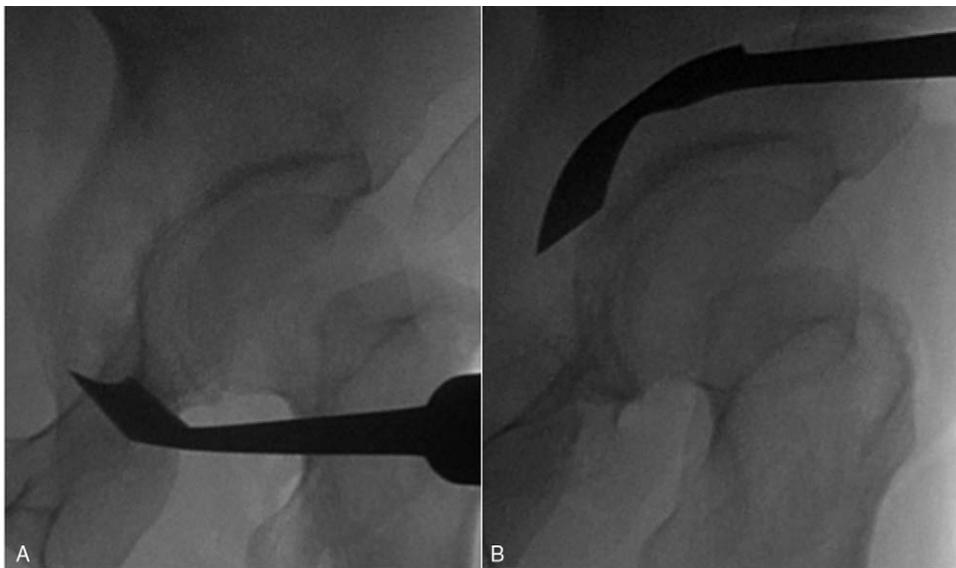


Figure 3. (A) The 1st real-time 3-dimensional computed tomography (3D-CT) image, One of the slices of the real-time serial CT images showing that the chisel was inserted at the ischium osteotomy region. The CT image allowed for confirmation that the osteotomy line had not reached the posterior column. (B) The 2nd real-time 3D-CT image. One of the slices of the real-time serial CT images showing that the curved chisel reached the quadrilateral surface. The CT image allowed for confirmation that C-shaped osteotomy line could ultimately be connected with the ischium osteotomy line.

allows a wider visual field and enables C-shaped osteotomy of the acetabulum in a less invasive way, even though it is used a small incision. However, osteotomy of the ischium cannot be done under direct visualization and must be done under fluoroscopy. Furthermore, it is also difficult to confirm the quadrilateral surface under direct visualization, and the osteotomy needs to be performed by relying on the curve of the curved chisel that was developed for CPO. Naito states that the osteotomy line of the quadrilateral surface should pass 1-finger width in front of the sciatic notch^[8]; however, anatomically, the space between the sciatic notch and the posterior line of the hip joint is quite narrow. In addition, the curved chisel needs to meet the osteotomy line by the ischium chisel below the hip joint, passing through this narrow passage from the superior portion of the quadrilateral surface. Even for the seasoned surgeon, if the chisel goes toward the anterior side it could pose a risk for intra-articular osteotomy,

and if the chisel goes toward the posterior side it could pose a risk for posterior column fracture. Therefore, care should be exercised. Posterior column fracture and intra-articular osteotomy during surgery have been reported as complications during CPO and PAO.^[11,12] To solve these issues, Otuki et al reported that they created a custom-made cutting guide according to the preoperative CT data from individual patients and performed CPO.^[13] Additionally, there have been excellent reports regarding RAO and CPO with navigation.^[14-16] The sphere image aligned with the curvature radius of the curved chisel was created during preoperative 3D planning, which then created the osteotomy line by placing the rotational center of the sphere image at the center of the femoral head and performed osteotomy with navigation. Hayashi performed 30 cases of CPO with navigation and 23 cases of CPO without navigation and examined the accuracy of osteotomy position compared with preoperative 3D-CT planning. They concluded that the replication of a more accurate osteotomy line was made possible by using navigation compared to the conventional method.^[15] However, osteotomy of the pubis and ischium is difficult to perform using an osteotomy line created by the sphere image through preoperative planning using navigation, and this relies on the fluoroscopy and the experience of the surgeon.

The 3D-CT images using Artis zeego were taken twice during surgery: at osteotomy of the ischium and at osteotomy of the quadrilateral surface. It was possible to confirm in real-time during surgery that the curved chisel from superior portion and the ischium osteotomy line crossed in front of the sciatic notch. Furthermore, image capturing was very smooth to reach the surgical table, and both the imaging and operation time were shorter compared to CPO using conventional fluoroscopy due to the fact that Artis zeego moves automatically to the operative field and the stress during operation for the surgeon was extremely low. Additionally, the curved chisel was made from stainless steel; however, there were hardly any metal artifacts in the images, and it was possible to confirm the tip of the chisel with certainty. The problem regarding this method is intraoperative



Figure 4. Postoperative anteroposterior radiograph of the left hip after curved periacetabular osteotomy.

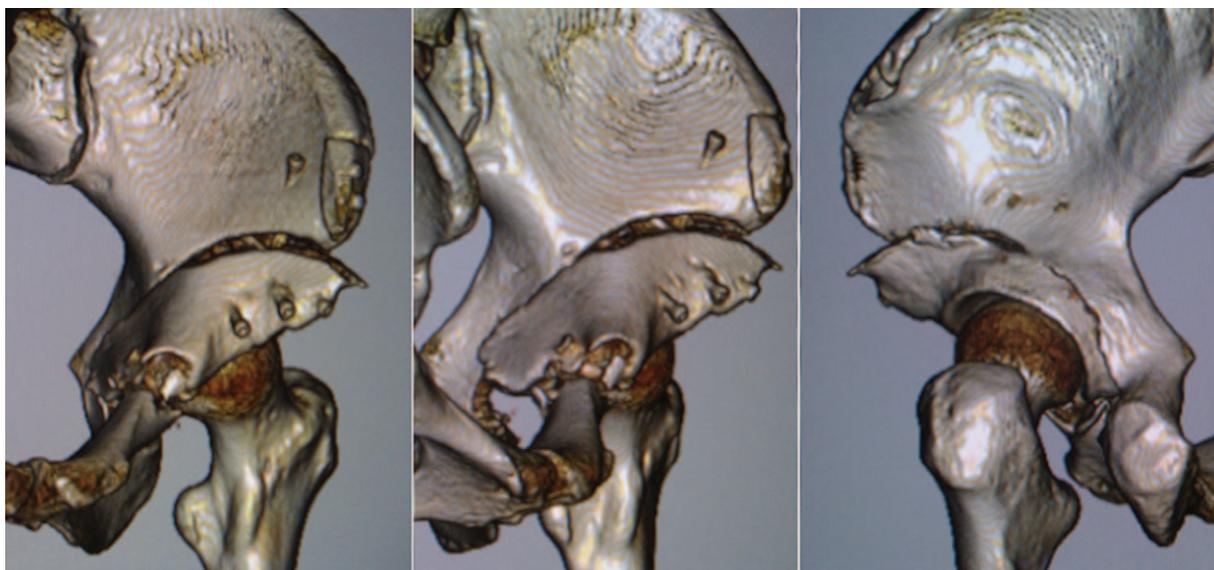


Figure 5. Postoperative 3-dimensional computed tomography (3D-CT). The postoperative CT image was showing the C-shaped osteotomy line with neither posterior column fracture nor intra-articular osteotomy.

radiation exposure.^[17,18] To keep the intraoperative radiation exposure level to a minimum, intraoperative CT imaging was limited to only 2 times. In the present case, the total radiation exposure during CPO using the real-time 3D-CT images with Artis zeego was 321 mGy. Schuetze et al proposed that the distribution of radiation exposure was dependent on the anatomical region, and the highest scatter radiation was measured in the pelvis region by cadaveric study.^[19] The software for Artis zeego automatically adapts the radiation dosage to the anatomic region to assure a constant image quality. In a clinical study with spine surgery, Kageyama et al compared the irradiation dose and the accuracy of the percutaneous pedicle screws angle between the conventional C-arm fluoroscopy group (5 cases) and the Artis zeego group (12 cases). Results have been reported that the placement accuracy was higher in the Artis zeego group, and the irradiation dose was significantly lower in the C-arm group (462 mGy vs 102 mGy; $P=.0013$).^[20] Approximately 2 times the irradiation dose was indicated in the Artis zeego group. On the contrary, Kageyama et al also compared the irradiation dose and time between the initial 6 cases and the later 6 cases. Irradiation time and dose were significantly lower in the later 6 cases. Irradiation time and dose gradually decreased, indicating a learning curve.^[20] Additionally, Kraus et al proposed the low-dose radiation exposure protocol for the spinal surgery with Artis zeego. The reduced dosage protocol can be drastically reduced the irradiation dose in comparison to routine CT and high-dose protocol with Artis zeego, and produced good image quality in the cadaveric study.^[21] Following the papers, it can be considered that it is possible to reduce the radiation exposure for the acetabular region by the regulation of the effective dose.

The limitation of this article is that the long-term clinical outcome and progression of osteoarthritis was not evaluated due to it being a report regarding the convenience and safety of the new operative method. Furthermore, a comparative discussion has not been made on this operative procedure with the conventional CPO with fluoroscopy and methods combining CPO with navigation. To the authors' knowledge, this is the 1st

report performing CPO using Artis zeego, and the 1st in the world to discuss the benefits of Artis zeego in pelvic osteotomy.

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