

Computed tomography measurement of acetabular dimensions

Normal values for correction of dysplasia

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Background A successful periacetabular osteotomy includes reliable planning based on radiographs and CT scanning. However, we lack normative CT values in planning realignment of the osteotomized acetabulum.

Patients and methods We retrospectively studied 70 hips that had been CT-scanned. Patients who showed no signs of developmental disturbances in either of the hip joints were eligible for the study. Sex differences were also studied.

Results The AA-angle, CE-angle, ACE-angle and AcetAV-angle, depicting frontal, sagittal and horizontal alignment, averaged 3° (SD 4°), 41° (7°), 31° (5°) and 21° (7°), respectively. The upper normal value (+ 2SD) for the AA-angle was 12°, normal range ($\pm$ 2SD) for CE-angle was 27°–55°, lower normal value ($-$ 2SD) for the ACE-angle was 22°, and normal range ($\pm$ 2SD) for the AcetAV-angle was 6°–35°. However, comparison of mean angles in women with those in men showed a statistically significant difference for the AA-angle and AcetAV-angle, but we found no significant differences between the mean figures for right and left hips.

Interpretation Knowledge of the normal dimensions of the acetabulum is essential in the diagnosis of the type and severity of DDH, as well as in preoperative planning. Accurate estimation of the normal contact surface orientation permits correct realignment of the osteotomized acetabulum

shallow and anteverted hip joint contact surface with deficient lateral, anterior and superior coverage of the femoral head is what characterizes the pathoanatomy of acetabular dysplasia. Rather than a hemisphere, the dysplastic acetabulum is typically only one-third of a sphere (Murphy et al. 1990).

In addition to relieving pain, the objective of reconstructive osteotomies in the treatment of DDH in adults is to achieve good containment of the femoral head within the acetabulum and thus diminish the risk of future degenerative changes. This is accomplished by reorienting the acetabulum to achieve improved loading conditions at the joint surface (Hipp et al. 1999). This improvement of joint mechanics reduces the pathologically high pressure on the articular cartilage. It is widely accepted that progression of secondary osteoarthritis may be reduced—or even halted—by a better distribution of pressure on the acetabular contact surface.

The anteroposterior (AP) weight bearing view of the pelvis is the most important radiograph for diagnosing and defining acetabular dysplasia. The center-edge angle (CE-angle) (Wiberg 1939) and acetabular index angle (AA-angle) (Tönnis 1987) already reliably provide information about potential candidates for periacetabular osteotomy. When surgery is considered, CT and reformats in 3 planes offer tools to assess the morphology of dysplastic hip (Klaue et al. 1988). This makes it possible to determine the varying types and degrees of acetabular deficiency and to plan the appropriate acetabular realignment.

The term developmental dysplasia of the hip (DDH) has replaced congenital dysplasia of the hip (CDH) in order to cover residual dysplasia. An oblique and

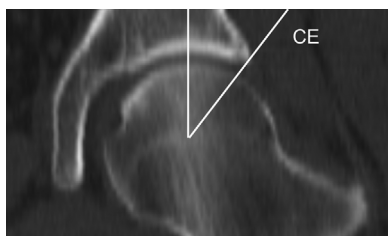


Figure 1. The lateral center-edge angle of Wiberg (CE-angle) is measured from a 2D coronal reformat through the center of the femoral head. It is the angle between the vertical axis of the pelvis and a line running through the center point and the lateral acetabular margin.

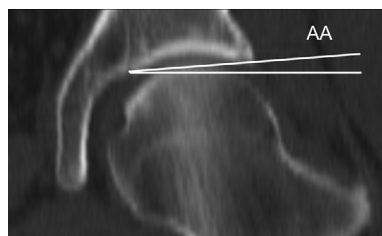


Figure 2. The acetabular index angle (AA-angle, lateral tilt of the acetabulum) is measured from a coronal 2D reformat through the center of the femoral head. It is the angle between the pelvic horizon and a line through the lateral rim of the acetabulum and the superior edge of the fovea, which is approximately a line along the sourcil.

To date, we have performed more than 350 hip osteotomies according to a modified method first introduced by Professor Reinhold Gantz. However, we still lack reliable information about the normal hip structure, which would allow us to set more precise goals for acetabular realignment. This was the primary aim of the present study, i.e. to assess, using CT, the normal contact surface dimensions and alignment of the acetabulum for use in diagnosis of dysplastic hips. We were also interested in determining the variations that occur in normal hips, and any sex differences.

Patients and methods

This retrospective study was performed at the ORTON Orthopaedic Hospital, Invalid Foundation. Using our hospital's archiving system, we gathered information on all hip CT scans performed between 1994 and 2004. In this series of consecutive patients, we excluded all patients with signs of osteoarthritis, arthritis, congenital or developmental structural changes such as dislocation, subluxation or dysplasia, previous surgery or trauma that had deformed the hip joint. If one of the hip joints had manifestations of osteoarthritis, or congenital or developmental disturbances, both hips were rejected. Indications for the CT imaging study included a fresh fracture or old fracture or suspicion of fracture (21 patients), avascular necrosis (6 patients), a soft-tissue or bone tumor (4 patients), soft-tissue complaints (3 patients), suspicion of trochanter bursitis (2 patients), a snapping hip (2 patients), SI-joint complaints (1 patient),

and evaluation of foreign bodies (1 patient).

Of 40 patients (20 males with median age of 43 (14–78) years and 20 females with median age of 52 (14–79) years), 70 hips met the inclusion criteria. Of these patients, 30 had bilateral hips that were eligible for the present study, with median age 45 (14–79) years.

All patients had undergone a routine scan on a Picker2000 CT scanner (Philips Med. system, Cleveland, OH). The legs were fully extended and the feet stabilized in a neutral position. Helical 4-mm CT sections were obtained at a pitch of 1.5 and using the following parameters: kV 130, mAs 350–600, and standard algorithm. The helical data were reconstructed at 1-mm intervals and transferred to a diagnostic workstation. Images in the transaxial, coronal and sagittal planes were routinely reformatted through the centers of the femoral heads.

These center-points were used as a reference for the measurements of coverage of the acetabulum. All measurements of hip coverage were performed by the same radiologist (KT), who developed this procedure for evaluation of dysplastic hips prior to periacetabular osteotomy in our hospital.

CT evaluation

Following parameters were measured:

CE-angle, a measurement of the lateral coverage of the acetabulum above the femoral head in a coronal reformat (Figure 1).

Acetabular index angle (AA-angle, lateral tilt or loading zone of the acetabulum), which shows the lateral tilt or slope of the acetabular roof in a coronal reformat (Figure 2).

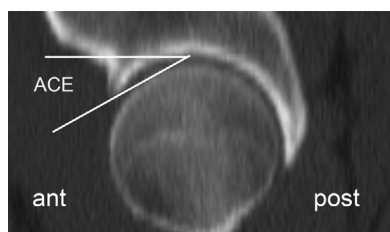


Figure 3. The superior-anterior angle (ACE-angle) is measured from a sagittal 2D reformat through the center of the femoral head. The angle is bound by the horizon and a line through the most superior point of the acetabular joint surface and anterior rim of the acetabulum.

Superior-anterior coverage of the acetabulum (anterior center-edge angle, ACE-angle), which is measured on a sagittal reformat and demonstrates the anterior coverage (Figure 3).

Acetabular anteversion (AcetAV-angle), which is measured on a transaxial reformat through the centers of the femoral heads (Figure 4) (Anda et al. 1991).

Anterior and posterior coverage (anterior acetabular sector angle, AASA, and posterior acetabular sector angle, PASA) are measured on the same transaxial plane (Figure 4) (Anda et al. 1986, 1991).

Statistics

Distribution of the values was assessed using descriptive statistical analysis. The relationship between parameters and the variables side and sex were assessed using multivariate analysis of variance (MANOVA). P-values < 0.05 were considered significant.

Results

Surgeons are used to planning and performing osteotomy mainly by following changes in the AA-angle, CE-angle, ACE-angle and AcetAV-angle. These angles averaged 3° (SD 4°), 41° (7°) 31° (5°) and 21° (7°), respectively. Thus, we estimated that in the normal population the AA-angle ranges (95%; mean ± 2SD) from -5° to 12°, the ACE-angle from 22° to 40°, and the AcetAV-angle from 6° to 35°. However, comparison of the mean angles in female patients with those in male patients showed a statistically significant differ-

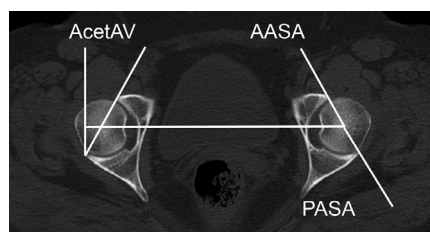


Figure 4. A transaxial 2D reformat through the centers of the femoral heads is used for the measurement of acetabular anteversion (AcetAV), anterior acetabular sector angle (AASA) and posterior acetabular sector angle (PASA). AcetAV is the angulation between a line combining the anterior and posterior margins of the acetabulum and a line perpendicular to the intercapital centerline. AASA and PASA are the angles of the intercapital centerline and lines from the centerpoint of the heads to the anterior and posterior rims of the acetabulum.

Table 1.

	AcetAV-angle	AA-angle	ACE-angle
Female hips			
mean (SD)	23 (7)	1 (4)	30 (4)
range ^a	10–37	-6–8	22–39
Male hips			
mean (SD)	17 (6)	5 (5)	31 (4)
range ^a	4–30	-6–15	24–38
P-value	< 0.01	< 0.05	0.5
^a mean ± 2SD			

Table 2.

	AASA	PASA	CE-angle
All hips			
mean (SD)	66 (14)	104 (16)	41 (7)
range ^a	39–93	72–137	27–55
Female hips			
mean (SD)	63 (11)	104 (25)	43 (7)
range ^a	41–86	54–154	29–57
Male hips			
mean (SD)	67 (13)	103 (11)	39 (7)
range ^a	42–92	81–125	26–52
P-value ^b	0.4	0.8	0.07
^a mean ± 2SD			
^b male versus female hips			

ence for the AA-angle and AcetAV-angle (Table 1). In Table 2, the means for the CE-angle—which is of crucial importance in diagnosing dysplasia and also change towards normal after surgery— and

anterior and posterior coverage are presented, both for all hips and for hips according to sex. Means $\pm$ 2SD are given as an estimate of the variation in the normal population.

We observed no significant differences between the mean figures for the right and left hips for any of the above parameters.

Discussion

We estimated ranges of normal variation in surgically relevant angles used in hip osteotomies and found similar values for right hips and left hips. However, we found a statistically significant difference in mean figures for AA- and ACE-angles between male and female hips.

We included patients who had no history or radiological signs of congenital, developmental or degenerative joint disorders. All the adolescents and adults, regardless of age, who met the inclusion criteria were enrolled in the study. Most of our patients were referred to CT examinations because of some kind of acute trauma, pain or soft-tissue problem. The anatomical abnormalities of DDH lead to increased contact peak pressure on a reduced contact area, which may predispose the patient to development of an osteoarthritis (Trumble et al. 1999, Sanchez-Sotello et al. 2002). For this reason, we excluded patients with signs of even mild degenerative osteoarthritis in one or both hips from the present study. This resulted in an unexpectedly long period of time for collection of this material.

A routine radiographic evaluation of DDH includes a functional AP radiograph of the pelvis, taken under weight-bearing conditions to show the mechanical aspects of the pelvis and hip. A visual appraisal of the hip joints easily discloses faulty coverage of the femoral head. Two commonly used, accurate and rapid measurements are the lateral center-edge angle of Wiberg (CE-angle) (Wiberg 1939) for lateral coverage and the acetabular index angle of the weight-bearing zone of the acetabulum (AA-angle, also called AC-angle, i.e. acetabular cartilage angle) for the tilt of the superior joint surface (Tönnis 1987). These two measurements are considered accurate enough to enable screening of dysplastic from normal hips. A

radiographic view frequently used earlier was the faux-profile (Lequesne and de Sèze 1961), which is a true lateral radiograph of the acetabulum showing the superior-anterior coverage of the femoral head. These imaging techniques offer a tool for diagnosis, but do not contribute sufficiently to current preoperative planning. Surgeons seem to need preoperative measures in the dimensions they can reliably control during surgery.

Today, preoperative evaluation of DDH for joint-preserving reconstructive surgery in our departments involves both conventional radiology and CT, sometimes complemented with MR. CT-imaging and 3-dimensional reconstruction offer reliable measurements without undesirable and disturbing superimposition of bony structures. CT angular measurements are reportedly convenient and rapid for routine diagnostic work as well as for demanding preoperative analysis in 3 dimensions (Haddad et al. 2000, Tallroth 2005). Additionally, CT evaluations provide clinicians with the information they need to choose suitable candidates for surgery, and to avoid for example patients with severe osteoarthritis not detectable in plain radiographs. Furthermore, it is of paramount importance to be able to define the goals of surgery and to plan appropriate adjustments.

In the report by Janzen et al. (1998), the CE-angle in 15 normal hips was 33° (SD 10), which is in accordance with our observations. In a study of 49 normal hips, Murphy et al. (1990) reported a mean CE of 38° (SD 10), which also corresponds to our calculations. The same authors also measured the ACE containment angle and found it to be 28° (SD 7.9). This observation is comparable with the findings of Lequesne and de Sèze (1961) in their original report based on standing radiographs, in which a normal ACE was 25°, an angle of 20°–25° was borderline, and an angle smaller than 20° was pathological. Our measurements in this present study were quite similar, i.e. 30° (SD 4).

In 1986 Anda et al. described a method that has been widely accepted for the measurement of AcetAV, AASA and PASA in the equatorial plane, i.e. a plane passing transaxially through the centers of the femoral heads. They examined 41 patients who had had an abdominal or pelvic CT examination. Patients with hip joint abnormalities on the scout view or the CT slices were excluded. Accord-

ing to their calculations, normal values for AcetAV were 19° (SD 4.5°) for men and 22° (SD 5.1°) for women; normal values for AASA were 64° (SD 6.1°) for men and 63° (SD 6.1°) for women, and normal values for PASA were 102° (SD 8.4°) for men and 105° (SD 7.9°) for women. Our investigation confirms these observations, which indicates that these containment angles are rather constant. It is noteworthy that the small gender difference was of the same magnitude in each case. The above observations, including ours, imply that surgeons should take the slight variation between men and women into account when planning and performing hip surgery. The results highlight the importance of realizing normal values for acetabular orientation.

To allow realignment of the acetabulum without injury to the joint surfaces, the acetabulum is osteotomized extraarticularly. Thus, during surgery, surgeons can control the extent of correction in all three planes by, for example, placing parallel K-wires to the osteotomized fragment and to adjacent pelvic bone and measuring the angles between the K-wires 3-dimensionally. Also, during surgery, an image intensifier can be used to assess the amount of correction, but only in AP view. We have found from experience in our hospital that surgeons prefer to follow the turn of the disengaged acetabulum in the same planes as the CT reformats appear. In the frontal plane, they tend to look at the change in AA-angle mostly, instead of the CE-angle, because the former seems to be easier to follow during surgery with image intensifier by, for example, placing a ruler or a K-wire horizontally and viewing the acetabular sourcil against it. They also prefer sagittal CT reformats instead of radiographs when planning the forward turn of the fragment. Furthermore, it has become evident that in cases with even a slight subluxation of the femoral head, a sagittal reformat through the midpoint of the loading area of the acetabulum is more useful and reliable than a reformat through the center of the femoral head.

Contributions of authors

KT was involved in the design of the study, collected all the CT material and made the measurements, as well as drafting

the manuscript. JL participated as an orthopedic surgeon in the design of the study, performed all the data analyses and statistical analyses and was involved in preparation of the manuscript. Both authors read and approved the final manuscript.

No competing interests declared.

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