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Anatomical Variations with Joint Space Measurements on CT

MEHMET DEMIR[1], AYFER MAVI[1], ERDEM GÜMÜSBURUN[1], METIN BAYRAM[2] and SAVAS GÜRSOY[3]

[1]*Department of Anatomy, Faculty of Medicine, Gaziantep University, Turkey.*

[2]*Department of Radiology, Faculty of Medicine, Gaziantep University, Turkey.*

[3]*Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Gaziantep University, Turkey.*

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This study has been performed to demonstrate the type and frequency of the anatomical variations of the sacroiliac joint according to age, gender, Body Mass Index and childbirth, and the influence of the anatomical variants to the uniformity and width of the joint space.

It was conducted on 400 consecutive patients without sacroiliac complaint who underwent pelvic CT scanning for various reasons. Patients' ages were 15 or above.

Anatomical variants that we observed were accessory sacroiliac joint (70 patients, 17.5%), iliosacral complex (38 patients, 9.5%), bipartite iliac bony plate (22 patients, 5.5%), semicircular defects on iliac/ sacral side (19 patients, 4.8%), crescent like iliac bony plate (14 patients, 3.5%) and ossification centers (4 patients, 1.0%). The mean joint space width of the 400 patients was 1.72±0.57 mm (from 0.77 mm to 4.39 mm). In adults below 40 years of age, the measured width was 2.49±0.66 mm. In older patients, 1.47±0.21 mm. Joints which presented anatomical variants (206 articulations) had a non-uniform joint space in 164 (79.6%), whereas uniform joint space were seen in 42 (20.4%) articulations. The joint width were less than 2 mm in 193 (93.7%) articulations and in 13 (6.3%) articulations were greater or equal to 2 mm.

This study has demonstrated that anatomical variations and joint space are independently related to age, gender, Body Mass Index and childbirth in patients. We believe that all this information is helpful to interpret and examine the sacroiliac computed tomography images.

It is generally possible to get sufficient knowledge for diagnosis after inspection and physical examination in joint pathologies. Nearby, there are some joints which are restricted in the aspect of diagnosis of physical examination. The sacroiliac joint (SJ) is one of the most important examples of these. The nearest part of SJ to the surface is approximately 2 cm deep and it has not got an explicit joint movement. Thus, the information obtained from the physical examination cannot sufficient and the usage of the radiological imaging methods gain importance for the diagnosis of SJ diseases (14). The plain radiography has known limitations mainly due to poor sensitivity in the early stages of the disease. These S-shaped joint of structures course obliquely from a lateral to a medial position, thereby causing substantial overlap of the ilium with the sacrum on standard anteroposterior projections of the pelvis in the supine position, which obscures the joint space (4). After the usage of MRI

Tel: +90- 348- 814- 3095 Fax: +90- 348- 813- 9392 E-mail: mdemir@gantep.edu.tr

and especially CT imaging, methods had improved innovations in the diagnosis of SJ diseases (9,8,5). It is necessary to know the normal structures of SJs to determine any kind of pathology. SJs have a lot of structural variations and show some anatomical changes due to the age (10). Because of this, comprehensive radiological studies allow us to distinguish the normal and the pathologic appearance and they would be very useful for the diagnosis of SJ diseases.

The aim of this study is to demonstrate type and frequency of the anatomical variations of the SJ according to age, gender, Body Mass Index (BMI) and childbirth, and the influence of the anatomical variants to the uniformity and width of the joint spaces in a series of 400 patients.

MATERIALS AND METHODS

The SJs of 400 patients were studied with the expectation of reference to variations in anatomic configuration on the SJ as described in the literature (10). In addition, we measured the joint width of the patients with or without presented anatomical variants. Our study group included patients without diseases of the SJ. Patients with inflammatory sacroiliitis or other arthropathies, endocrine disease, history of severe pelvic trauma, chronic or repeated episodes of low back pain were excluded from this study. All patients were informed of the aim of this study. Age, gender, physical data (height and weight) and childbirth in women were noted in each patient. Patients with BMI [weight (kg)/ height (m^2)] greater than 28 were defined as obese in both gender, while men with BMI between 20-22 and women with BMI between 21-23 respectively were considered as normal weight (3). All examinations were performed using a Hitachi 1000W CT system. The scan parameters that we used were as follows: 200 mA, 120kV, 1.9 s data question time, with the patient supine. All patients were scanned in the axial plane with no gantry tilt. Section thickness ranged from 5 to 10 mm. The CT sections through the joint were printed on bone window settings and were analyzed with respect to anatomical variants (deviations from the usual anatomical structure of the articular facets of the sacrum and ilium) of the SJ. Measurements of the joint space were obtained either on the computer with cursors or by use of calipers and a standard computer grid. The joint space was considered uniform when no differences were observed, greater than 0.3 mm between measurements at different sides of the anterior portion of the joint space. Otherwise, the joint space was considered non-uniform (15). Statistical analysis was performed using the chi-squared test. A level of $p < 0.05$ was considered to be significant.

RESULTS

The group consisted of 204 (51%) men and 196 (49%) women between the ages of 15 and 85 years (51.69 ± 16.51 years). The mean joint space width of the 400 patients was 1.72±0.57 mm (from 0.77 mm to 4.39 mm). In adults below 40 years of age the measured width was 2.49±0.66 mm and in older patients 1.47±0.21 mm. Measurements and uniformity of the SJ space in relation to gender, age, BMI and childbirth are shown in Table 1. We observed a higher incidence of non-uniform joint space (271 patients, 89.1%) (p=0.000) and joint space width of less than 2 mm (241 patients, 79.3%) (p=0.000) in patients older than 40 years compared to the young. Women with 3 or more childbirths had a higher prevalence of joint space width of less than 2 mm (93, 59.6%) (p=0.000) and non-uniform joint space (156, 100%) (p=0.000) compared to women with 2 or less childbirths. In this study, women (174, 88.8%) demonstrated a higher incidence of non-uniform joint space than men (p=0.000). Whereas, men (152, 74.5%) presented a joint width of less than 2 mm more than women

(p=0.000). Obese patients (77 patients, 98.7%) had a higher prevalence of non-uniform joint space compared to normal weight patients (p=0.000) (Table 1).

TABLE 1.
Measurements and uniformity of the SJ in relation to gender, age, BMI and childbirth.

Sacroiliac joint	Men (n=204)		Women (n=196)		<40 yrs (n=96)		≥40 yrs (n=304)		Obese (n=78)		Normal Weight (n=61)		<3 Childbirth (n=40)		≥3 Childbirth (n=156)	
	no	%	no	%	no	%	no	%	no	%	no	%	no	%	no	%
<2 mm	152	74.5	100	51.0	11	11.5	241	79.3	47	60.3	44	72.1	7	17.5	93	59.6
≥2 mm	52	25.5	96	49.0	85	88.5	63	20.7	31	39.7	17	27.9	33	82.5	63	40.4
uniform	78	38.2	22	11.2	67	69.8	33	10.9	1	1.3	21	34.4	22	55.5	-	-
non-uniform	126	61.8	174	88.8	29	30.2	271	89.1	77	98.7	40	65.6	18	45.0	156	100.0

TABLE 2.
Variations of the SJ on 400 CT examinations in relation to gender, age, BMI and childbirth.

Variations	Patients (n=400)		Men (n=204)		Women (n=196)		<60 yrs (n=247)		≥60 yrs (n=153)		Obese (n=78)		Normal Weight (n=61)		<3 Child-birth (n=40)		≥3 Childbirth (n=156)	
	no	%	no	%	no	%	no	%	no	%	no	%	no	%	no	%	no	%
Accessory SJ	70	17.5	39	19.1	31	15.8	33	13.4	37	24.2	23	9.5	9	14.8	2	5.0	29	18.6
Iliosacral complex	38	9.5	22	10.8	16	8.2	11	4.5	27	17.6	12	5.4	5	8.2	1	2.5	15	9.6
Bipartide iliac bony plate	22	5.5	16	7.8	6	3.1	8	3.2	14	9.2	7	9.0	2	3.3	1	2.5	5	3.2
Semicircular defects	19	4.8	1	0.5	18	9.2	6	2.4	13	8.5	7	9.0	-	-	3	7.5	15	9.6
Crescent like iliac bony plate	14	3.5	-	-	14	7.1	5	2.0	9	5.9	2	2.6	1	1.6	3	7.5	11	7.1
Ossification centers	4	1.0	1	0.5	3	1.5	2	0.8	2	1.3	-	-	-	-	1	2.5	2	1.3

In 400 patients, the frequency order of anatomical variants of SJs was as follows: 1. accessory sacroiliac joint (70 patients, 17.5%); 2. iliosacral complex (38 patients, 9.5%); 3. bipartite iliac bony plate (22 patients, 5.5%); 4. semicircular defects on iliac/ sacral side (19 patients, 4.8%); 5. crescent like iliac bony plate (14 patients, 3.5%) and 6. ossification centers (4 patients, 1.0%) (Table 2). Accessory SJ was the most common anatomical variant identified in 70 (17.5%) patients, 46 (11.5%) unilateral and 24 (6.0%) bilateral. The joint is situated between the iliac and the sacral articular surfaces at the posterior portion of the SJ, from the level of the first to the second sacral foramen. On CT images, accessory SJs' articular surfaces resembled an osseous projection from the ilium to the sacrum (Fig. 1). We observed a higher incidence of accessory SJ in patients older than 60 years (37 patients, 24.2%) compared to the young (p=0.006) (Table 2). In this study, this variant was more common in men, but it was not statistically significant. Accessory SJ was more common in

obese patients (23 patients, 29.5%) than normal weight patients (p=0.041). Women with 3 or more childbirths (29, 18.6%) had a higher prevalence of this variation compared to women with 2 or less childbirths (p=0.036) (Table 2). We obtained 94 accessory SJs of which 80 (85.1%) articulations were non-uniform, 14 (14.9%) of them were uniform. The width of joint space was less than 2 mm in 92 (97.8%) articulations and 2 (2.2%) articulations were greater than 2 mm or equal. We observed radiological changes such as subchondral sclerosis (29 joints, 29.8%), osteophytes (13 joints, 13.8%) and ankyloses (4 joints, 4.3%) on the articular surfaces of joints.

The second more common anatomical variant is the "iliosacral complex" which was formed by an iliac projection inserting to a complementary sacral recess (Fig. 2). We observed it in 38 (9.5%) patients, 29 (7.3%) unilateral and 9 (2.2%) bilateral (Table 2). This anatomical variant was located at the posterior portion of the SJ from the level of the first to the second sacral foramen. Patients older than 60 years (27 patients, 17.6%) demonstrated a higher prevalence of iliosacral complex compared to the young (p=0.000). Obese women (9, 17.0%) presented this variant more frequently than normal weight women (p=0.021) (Table 2). This variant was more common in men than women, but it was not statistically significant. We observed 47 articulations, which presented iliosacral complex. 38 (80.9%) of them were non-uniform and 9 (19.1%) were uniform. The width of joint space was less than 2mm in 44 (93.6%) articulations. In 3 (6.4%) articulations, it was greater than 2 mm or equal.

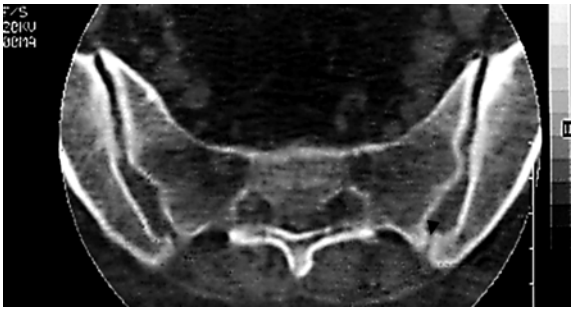

FIG. 1. 45-year-old woman with left accessory SJ (arrowhead) on a 5 mm CT section.

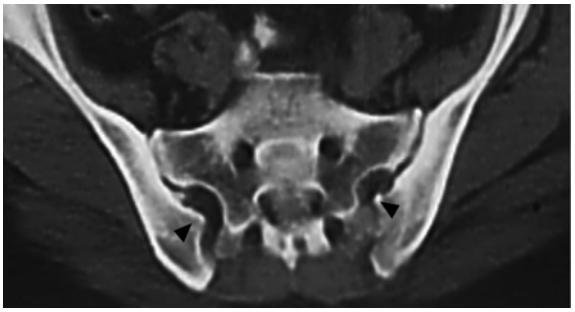

FIG. 2. CT scan from a 56-year-old man shows bilateral iliosacral complex (arrowheads). This variation was formed by an iliac projection inserting to a complementary sacral recess.

The third anatomical variant was bipartite iliac bony plate, which was in 22 (5.5%) patients unilaterally. In this study, men (16, 7.8%) demonstrated a higher incidence of this anatomical variant than women (p=0.036). Bipartite iliac bony plate was more common in patients older than 60 years (14 patients, 9.2%) compared to the young (p=0.012) (Table 2). It was located at the posterior portion of the SJ from the level of the first to the second sacral foramen. On CT images the appearance of the iliac bones look as bipartite (Fig. 3). We observed 22 articulations, which presented this figure. 20 (90.9%) of them were non-uniform and 2 (9.1%) were uniform. The width of joint space was less than 2 mm in 21 (95.5%) articulations. In 1 (4.5%) articulation joint, the space was greater or equal to 2 mm.

The fourth variant that we observed was semicircular defect in the articular surface. It was presented in 19 (4.8%) patients, 15 (3.8%) unilateral and 4 (1.0%) bilateral. Patients older than 60 years (13 patients, 7.8%) demonstrated a higher prevalence of the semicircular defects compared to the young (p=0.006) (Table 2). Obese patients (7 patients, 9.0%) presented this variant more frequently than normal weight patients (p=0.018). Semicircular defect was more common in women (18, 9.2%) than men (p=0.000). It was located at the posterior portion of the SJ from the level of the first to the second sacral foramen. On CT scans, bilateral appearance of this anatomical defect resembles a foramen (Fig. 4). The joint space was non-uniform in 15 (65.2%) articulations. In 8 (34.8%) of them, it was uniform. The width of the joint space was less than 2 mm in 21 (91.3%) articulations and it was greater than 2 mm or equal in 2 (8.7%) articulations.

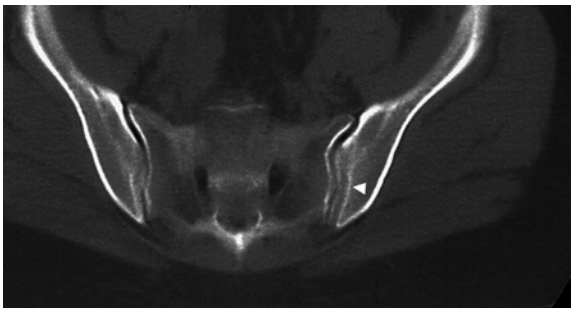

FIG. 3. 36-year-old woman with a bipartite iliac bony plate (arrowhead) unilaterally on the CT section.

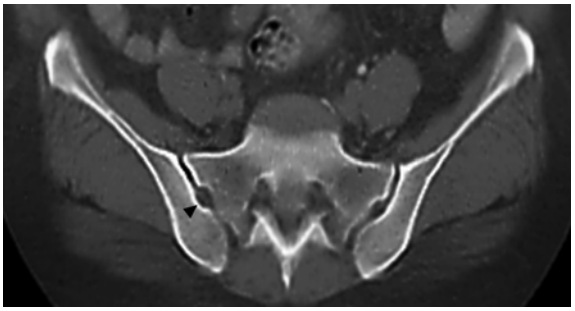

FIG. 4. CT scan from a 50-year-old man shows semicircular defects (arrowhead) at the articular surfaces of the sacrum and ilium.

The fifth variant was crescent like iliac articular surface in our study. It was present in 14 (3.5%) patients, 12 (3.0%) unilateral and 2 (0.5%) bilateral. We observed this variant only in women (14, 7.1%) (p=0.000). Crescent like iliac articular surface was more common in patients older than 60 years (9, 5.9%) than the young (p=0.041) (Table 2). On CT sections, crescent like iliac bony plate was accompanied by bulged sacral surface, and was demonstrated usually at the posterior portion of the SJ from the level of the first to the second sacral foramen (Fig. 5). We obtained 16 articulations, which presented this variant. 8 (50%) of them were non-uniform and 8 (50%) were uniform. The width of joint space was less than 2 mm in 12 (75%) articulations. In 4 (25%) articulations joint, the space was greater or equal to 2 mm.

The last anatomical variant that we obtained was ossification centers of the sacral wings, which was presenting as triangular osseous bodies within the joint space (Fig. 6). It was located at the anterior portion of the SJ and at the level of the first sacral foramen. We found this variant in 4 (1.0%) patients unilaterally. The joint space was non-uniform in 3 (75%) articulations. In 1 (25%) articulation, the joint space was uniform. The width of the joint space was less than 2 mm in 3 (75%) articulations and they were greater than 2 mm or equal in 1 (25%) articulation.

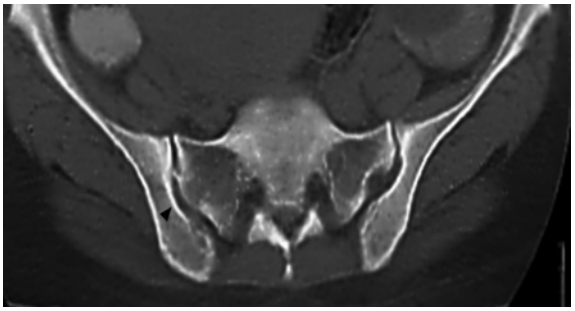

FIG. 5. 58-year-old woman with a crescent like iliac bony plate (arrowhead) unilaterally on the CT section.

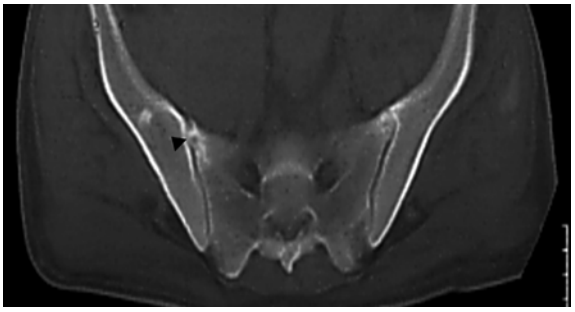

FIG. 6. Ossification center (arrowhead) of the right sacral wing presented between the iliac and sacral bony plates of SJ unilaterally in a 67-year-old woman.

DISCUSSION

The normal appearance of the SJ in our population was influenced by age, gender, BMI and childbirth. We measured the width of the joint space which presented these variants and found that all these joints are less than 2 mm and described the joint space as non-uniform. The joint space width in our series of 400 patients ranged from 0.77 mm to 4.39 mm and was related to age, gender, BMI and childbirth. Patients younger than 40 years of age usually had a uniform joint space measuring more than 2.49±0.66 mm in width. Older patients had a non-uniform joint space and the width was 1.47±0.21 mm.

A number of investigators have reported the presence accessory joints (2,7,10,12,13). These joints have been observed in 8% to 40% of samples. These studies are based on cadaver dissections (7,12,13), comparative studies (CT with cadaver dissection) (2), and CT imaging (10). In the literature, there are a few MR studies which evaluated the normal morphology of the SJ with regard to anatomical variations (1,6,11,16). Most of them used coronal MR images to perform their study (6,11,16). In these studies, accessory sacroiliac articulation were found in two patients (6,16). One of them compared MRI imaging with histological findings and concluded that the transitional zone of the SJs are rich in additional structures and vascular changes at the anatomical site of the bony channel. In addition, they mentioned that coronal MR imaging does not allow assessment of normal anatomy, variants or abnormalities of the ventral and dorsal margins of the cartilaginous sacroiliac joint (11). In this study, obesity and childbirth in women increase the incidence of accessory SJ. We did not find any study which mentioned about the influence of the childbirth to the anatomical variations of the SJ. We observed the incidence of accessory joints 17.5% of 400 patients. The location of accessory SJ in our CT images were between the iliac and the sacral articular surfaces at the posterior portion of the SJ, from the level of the first to the second sacral foramen. The relation of accessory joint and gender was insignificant in our study.

Trotter (12) demonstrated in a comprehensive study of a higher prevalence of accessory joints in males than in females (40% and 21%, respectively) in 958 articulations. Whereas, in her other study (13), she observed this variant more in females than males. She explained that mothers carried the baby or young child on her back for a long period in East Africa and this situation must increase stress and strain on the SJ. Ehara *et al.* (2) examined 100 CT scans of the pelvis and 56 adult dried skeletons. They indicated the incidence of the accessory SJs for CT 13% and for adult skeletons 16%. Patients age were 19-84 years, who underwent CT. Age, gender, and race of the skeletons were unknown in their study. They termed the accessory SJ as ''common variant'' and marked degenerative changes (ankylosis, sclerosis and osteophytes) on the auricular surface of the joint. They stated that some joints are truly diarthrodial and present at birth, but others are more commonly acquired fibrocartilaginous joints that result from the stress of weight-bearing. They reported that the accessory SJ is not rare and that it is visible on CT scans in many asymptomatic patients (2). Trotter (12) also found fibrocartilaginous articular surfaces in most of her cases, although hyaline cartilage was found in a few. She concluded that the joints are acquired in most of the cases (12,13). In previous studies, patients who showed accessory joint on the CT, have complain of low back pain and some complain that pressure over the accessory joint is pain full (10,7). Our patients stated that they did not have any complain for low back pain. We evaluated patients from 17 to 85 years and found that the accessory joint was the most common variant in our study. We also found accessory SJs presented a high incidence of involvement with degenenerative alterations (subchondral sclerosis, osteophytes and ankyloses). In addition, we measured the width of the joint space which presented this variant and found that all these joint spaces are less than 2 mm and described them as

non-uniform. We did not find any information about the anatomical variants in infant, to compare the results mentioned by Ehara *et al.* (2). There is only one MR study, which evaluated the normal morphology of SJ in 114 adolescent children, whose age ranged from 8 to 17. They reported the incidence of accessory SJ as 5% of 114 children, only in girls. In addition, they indicated the joint space mean width as 4.2±0.7 mm irrespective of age and sex (1). In our series adolescence joint space width was mostly ranged to 4.39 mm.

Prassopoulos *et al.* (10) observed bipartite iliac bony plate more in women than in men and the incidence was 4.1% in 534 patients. In our sample the prevalence was 5.5% for this variant. We observed it more in men than in women, and in older patients than in the young. Ossification centers were infrequent in our study group. We observed ossification centers in three women and in one man of 400 patients. Our results about the ossification centers were in agreement with the findings reported by Prassopoulos *et al.* (10). The other anatomical variants (iliosacral complex, crescent iliac bony plate and semicircular defects) were usually observed at both sides and were not associated with degenerative alterations. They were more common in women. Especially iliosacral complex was more seen in obese women. Crescent iliac bony plate and semicircular defects were related to the ages of the patients. Prassopoulos *et al.* (10) reported that these anatomical variants were more detected in women than in men and did not relate to patients age or BMI. In our study, the joint space which presented these variants (bipartite iliac bony plate, ossification centers, iliosacral complex, crescent iliac bony plate and semicircular defects) was less than 2 mm and mostly non-uniform. We believe that further studies will be needed to compare the results about the other five variants (bipartite iliac bony plate, ossification centers, iliosacral complex, crescent iliac bony plate and semicircular defects) of the SJs.

This study has demonstrated that anatomical variations and joint space are independently related to age, gender, BMI and childbirth in normal subjects. We believe that all this information is helpful to interpret and examine the sacroiliac CT images.

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