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# Pelvic CT Morphometry in Down Syndrome: Implications for Prenatal US Evaluation—Preliminary Results<sup>1</sup>

**PURPOSE:** To characterize pelvic morphometric differences in patients with and those without Down syndrome by using computed tomography (CT) and to determine useful indexes for ultrasonographic (US) evaluation.

**MATERIALS AND METHODS:** Pelvic CT scans in seven patients with Down syndrome and in 27 patients without Down syndrome were reviewed. Iliac angle, iliac length, sacroiliac joint angle, and anterior iliac wing separation were measured at superior, middle, and inferior transverse sacral levels. The effects of chromosomal status and transverse level were evaluated statistically.

**RESULTS:** Significant differences were found for mean iliac angle ( $P < .007$ ) and length ( $P < .005$ ) between patients without Down syndrome (angle, 75°; length, 8.4 cm) and those with Down syndrome (angle, 82°; length, 7.5 cm). Depending on the level of measurement, variations in iliac angle between patients without and those with Down syndrome were as much as 13° and 15°, respectively, and variations in length were as much as 1.6 cm and 0.9 cm, respectively. The greatest differences were at the middle sacral level. Sacroiliac joint angle and the anterior iliac wing separation were not different between groups.

**CONCLUSION:** Patients with Down syndrome had a larger mean iliac angle and a shorter mean iliac length. The most pronounced differences were at the middle sacral level, which suggests that this may be the optimal level for measuring these parameters at prenatal US.

Dysmorphologic features of the pelvic girdle at prenatal ultrasonography (US) have been investigated (1–4) as potential indexes of aneuploidy, especially of Down syndrome. Results from these investigations indicate the utility of measurement of the iliac angle and the iliac length in the transverse plane, but none of these studies controlled for the effects of potentially important covariates, such as transverse level and patient sex (1–8). Moreover, the morphometric indexes proposed to be useful for prenatal diagnosis have not been systematically validated with current imaging techniques in the postnatal pelvis.

The application of pelvic morphometry for the prenatal diagnosis of Down syndrome derives from postnatal studies (9–13) of frontal pelvic radiographs. Although these early postnatal results established a discordance in the pelvic profile between patients without and those with Down syndrome, the depiction of the pelvis on anteroposterior radiographs could not be correlated with transverse US depictions of the prenatal pelvis. A few postnatal studies (11–13) have involved examination of the transverse appearance of the pelvis in patients with Down syndrome, but these studies preceded the advent of computed tomography (CT) and were, therefore, severely limited. CT images depict the pelvic profile in well-defined transverse planes similar to those of prenatal US and, therefore, provide an opportunity to test for morphologic differences in a more rigorous and controlled fashion.

The purpose of this study was to use CT to characterize morphologic differences in the

transverse pelvic profiles of patients with Down syndrome and of those without Down syndrome while controlling for the effect of transverse level and to extrapolate these findings to prenatal US studies. Measurements of the pelvis included the iliac angle, iliac length, sacroiliac joint angle, and separation of the anterior iliac wings.

## MATERIALS AND METHODS

The records of all CT studies obtained from May 1985 to May 1996 were cross-referenced with the records of all patients with Down syndrome evaluated at our institution. From this, seven patients with Down syndrome (four female and three male patients) who had undergone pelvic CT were identified, and their CT studies were collected. Each patient with Down syndrome was matched for age, sex, and race to three or four patients without Down syndrome who also had undergone pelvic CT during the same period. Therefore, the study group consisted of 34 patients: seven with Down syndrome and 27 without Down syndrome. The ages of the matched sets were 6 months and 1, 3, 4, 7, 8, and 46 years. The matching for age was within 1 month for the 6-month-old patients and within 6 months for the older patients.

None of the patients had evidence of pelvic trauma, bone marrow abnormality, or other pelvic pathologic conditions. The patients underwent CT to evaluate for cancer ( $n = 12$ ), traumatic injury ( $n = 11$ ), or infection ( $n = 8$ ); for postoperative evaluation ( $n = 2$ ); or because of increased levels determined at liver function tests ( $n = 1$ ).

All measurements were performed by one observer (M.A.K.) who was not aware of the patient's chromosomal status. Measurements were performed at three pelvic levels: superior (at the level of the iliac crests), middle (at the middle level of the sacrum), and inferior (at the inferior level of the sacrum). Measurements included the iliac angle, iliac length, sacroiliac joint angle, and anterior iliac wing separation. The iliac angle is defined (1) as the angle formed by the convergence of lines drawn on the posterolateral aspect of the right and left wings of the ilium (Fig 1). The iliac length was measured from anterior to posterior along the length of the bone (Fig 2). We did not attempt to measure the length where the ilium was longest. The anterior iliac wing separation is the chord subtended by the iliac angle (Fig 1). The sacroiliac joint angle is

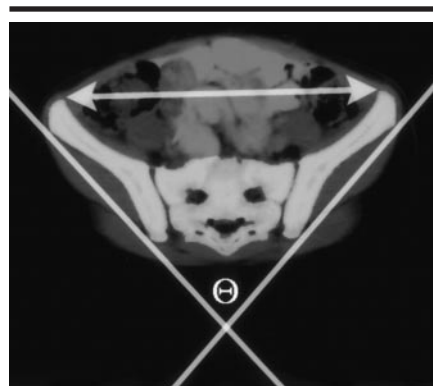
defined as the angle formed by a line drawn through the sacroiliac joint and a line drawn anterior to posterior and perpendicular to the coronal plane of the sacrum (Fig 2). Angular measurements were obtained by using a hand-held goniometer. Linear measurements were obtained by using the CT display scale. The means and SDs were calculated.

For each of the measured outcome variables (iliac angle, iliac length, sacroiliac joint angle, and anterior iliac wing separation), a set of mixed linear models was fit for each predictor variable (chromosomal status and transverse level). The mixed linear models allow estimation of the effect of an independent variable while controlling for all other variables, as well as for correlation between measurements within a patient. The predictive variables that exhibited a statistically significant effect were identified. Results were considered to be significantly different when the  $P$  value was .05 or less.

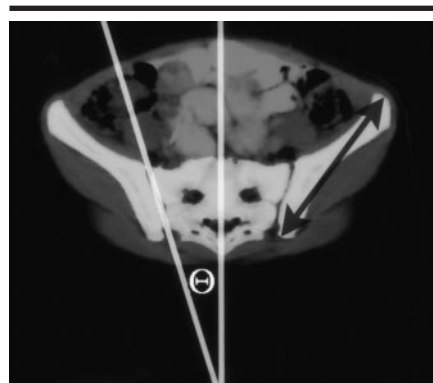
## RESULTS

One hundred eleven sets of measurements were obtained from the pelvic CT scans in the 34 patients. There were significant differences in mean values between patients with Down syndrome and those without Down syndrome for iliac angle ( $P < .007$ ) and iliac length ( $P < .005$ ). No significant difference was found for measurements of the sacroiliac joint angle ( $P = .498$ ) and anterior iliac wing separation ( $P = .119$ ) between the two groups. Further, no significant sex effect was demonstrated for any of the indexes, although the magnitude of the effect would have to be very large to be evident with these small sample sizes. The iliac angle did not vary systematically with age when age was examined as an independent variable.

In Table 1, summary statistics are given for the outcome measurements of iliac angle, iliac length, sacroiliac joint angle, and anterior iliac wing separation in patients without and those with Down syndrome. These values are averages across all categories of transverse levels and are intended to provide an overview of the data. The mean iliac angle was  $75^\circ$  in patients without Down syndrome versus  $82^\circ$  in patients with Down syndrome. This difference is schematically depicted in the composite CT image of transverse pelvic profiles in a patient without Down syndrome and a patient with Down syndrome (Fig 3). The range of iliac angle measurements was large:  $51^\circ$ – $95^\circ$  in pa-



**Figure 1.** Transverse CT scan shows measurements of the iliac angle ( $\theta$ ) and anterior iliac wing separation (double-headed arrow) in an infant with Down syndrome. The iliac angle is defined as the angle formed by the convergence of lines drawn on the posterolateral aspect of the right and left wings of the ilium. The anterior iliac wing separation is the chord subtended by the iliac angle.



**Figure 2.** Transverse CT scan shows measurements of the sacroiliac joint angle ( $\theta$ ) and iliac length (double-headed arrow) in an infant with Down syndrome. The sacroiliac joint angle is defined as the angle formed by a line drawn through the sacroiliac joint and a line drawn anterior to posterior, perpendicular to the coronal plane of the sacrum. The iliac length was measured from anterior to posterior along the length of the bone.

tients without Down syndrome and  $55^\circ$ – $105^\circ$  in patients with Down syndrome. The mean iliac length was larger in patients without Down syndrome (8.4 cm) than in patients with Down syndrome (7.5 cm). The range of iliac length measurements was substantial and corresponded to the wide range of patient age (Table 1).

In Table 2, the mean iliac angle and length measurements are given at the three transverse levels for patients without Down syndrome and for patients with Down syndrome. The greatest difference in the iliac angle between patients

**TABLE 1**  
Summary of Measurements Obtained across Levels in Patients with and Those without Down Syndrome

Measurement	Without Down Syndrome		With Down Syndrome		Difference	P Value
	Mean*	Range	Mean*	Range		
Iliac angle (degrees)	75 (10)	51–95	82 (11)	55–105	7	<.007
Iliac length (cm)	8.4 (3.4)	3.0–17.4	7.5 (2.5)	3.1–13.0	0.9	<.005
Sacroiliac joint angle (degrees)	20 (11)	3–40	22 (8)	7–36	2	.498
Anterior iliac wing separation (cm)	15.3 (4.8)	8.2–27.8	14.5 (4.0)	7.0–23.5	0.8	.119

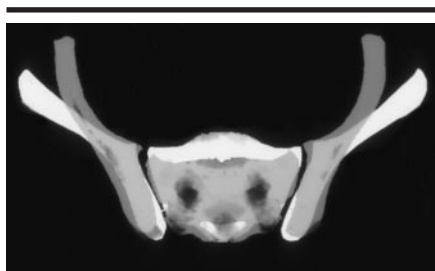
\* Number in parentheses is the SD.

**TABLE 2**  
Differences in Iliac Angle and Length Measurements Obtained at Different Transverse Levels

Measurement and Level	Without Down Syndrome		With Down Syndrome		Difference†
	Mean*	Range	Mean*	Range	
Iliac angle (degrees)					
Superior	82 (9)	65–95	89 (10)	67–105	7
Middle	73 (10)	54–85	81 (9)	65–95	8
Inferior	69 (8)	51–85	74 (9)	55–85	5
Iliac length (cm)					
Superior	7.5 (3.0)	3.0–14.0	2.0 (2.6)	3.1–12.2	0.5
Middle	9.1 (3.4)	4.6–17.4	7.9 (2.4)	4.8–13.0	1.2
Inferior	8.5 (2.9)	4.4–15.0	7.5 (2.8)	3.5–12.2	1.0

\* Number in parentheses is the SD.

† All differences were statistically significant ( $P < .001$ ).



**Figure 3.** Computer-rendered superimposition of transverse CT images of the pelvis in an infant with Down syndrome (white) and of that in an infant with a normal karyotype (gray). This composite image depicts the morphologic differences between the pelvis in a patient with Down syndrome and that in a patient without Down syndrome. The two images were superimposed by using standard image manipulation and graphics software (PHOTOSHOP; Adobe Systems, San Jose, Calif).

without and patients with Down syndrome was  $8^\circ$  at the middle part of the sacrum. The iliac angle varied by as much as  $13^\circ$  in patients without Down syndrome and by as much as  $15^\circ$  in patients with Down syndrome, depending on the transverse level selected for the measurement. The greatest difference in iliac

length (1.2 cm) between patients without and patients with Down syndrome also was observed at the middle part of the sacrum. The iliac length varied by as much as 1.6 cm in patients without Down syndrome and by as much as 0.9 cm in patients with Down syndrome, depending on the transverse level selected for the measurement.

## DISCUSSION

Prenatal US measurements of the fetal pelvis have only relatively recently been investigated as possible markers for Down syndrome (1–4). These preliminary results have indicated that the mean iliac angle in fetuses with Down syndrome is larger than that in fetuses without Down syndrome (1–3) and that iliac length in fetuses with Down syndrome is greater than that in fetuses without Down syndrome (4). These studies, however, did not control for the probable effect of transverse level on these indexes. Indeed, some observers (7) noted a wide variation in iliac angle that was dependent on the transverse level of measurement on prenatal US studies.

Morphometric differences are difficult to characterize with prenatal US because there are no standard transverse planes for comparison, and landmarks have not been established with which these planes could be defined. For these reasons, we compared the transverse pelvic profiles in patients with and patients without Down syndrome by using CT, which provides well-defined, serial transverse images. The purpose of this study was to explore the differences in pelvic morphology between patients with and those without Down syndrome under ideal circumstances and thereby identify the most promising indexes and transverse levels for prenatal evaluation. Such an investigation would provide preliminary guidance for the larger prospective prenatal US investigations that are needed to fully validate this approach but that will take many months and years to complete, given the relatively low prevalence of fetuses with Down syndrome encountered at most US facilities.

Historically, the radiographic diagnosis of Down syndrome in infants was based partly on characteristic dysmorphic features observed on anteroposterior radiographs of the pelvis. Pelvic bone abnormalities—including widened, flared iliac wings with an increased outward curvature—were found (8) to be present in up to 80% of newborns with Down syndrome. Morphometric analysis was primarily dependent on measurements of pelvic contours around the hip at the acetabular roof and lateral margin of the iliac bone.

Some investigators (11–13) at that time attempted to explain this anteroposterior radiographic appearance of the pelvis in patients with Down syndrome by examining the pelvis from the craniocaudal perspective. In two studies (11,12), cadaver specimens, which were inspected visually (11,12), were used; in a third study (13), infants were placed in the lithotomy position, and radiography was performed from below through the long axis of body. The authors of these studies offered several possible explanations for the appearance of the pelvis in patients with Down syndrome: The posterior part of the ilium has a markedly dorsal curvature in infants with Down syndrome (13), there is outward rotation at the sacroiliac joint (12), and the iliac wings are sprung open and angulated caudad (11).

In this current postnatal study, we found that the iliac wings were indeed more divergent in patients with Down syndrome. Specifically, the iliac wings in patients with Down syndrome tended to be oriented in a more coronal plane and

to be shorter than the iliac wings in patients without Down syndrome. This dorsal angulation did not seem to result from outward rotation of the sacroiliac joint but rather from the intrinsic curvature of the wing (Fig 3). The iliac angle, formed by the convergence of the iliac wings, was measurably larger in patients with Down syndrome than in patients without Down syndrome, but the iliac angle varied substantially with transverse pelvic level in both groups. Of importance, the variation in iliac angle measurements obtained at different transverse levels was greater than the difference in iliac angle measurements between patients without and patients with Down syndrome. These results suggest that it is imperative that the transverse level of measurement be standardized if the indexes are to be valid. Our results further demonstrated that the postnatal iliac length was shorter in patients with Down syndrome than in patients without Down syndrome. For both iliac angle and iliac length, the middle part of the sacrum was the level where the greatest discrepancies were evident between patients with and those without Down syndrome.

Curiously, the authors of a prenatal study (4) of iliac length suggested that this measurement is longer in fetuses with Down syndrome, which is contrary to what we found in the present postnatal study with CT. One possible explanation for this discrepancy may be the failure in the prenatal study to account for the transverse level of measurement. Additional prenatal studies in which a transverse level of measurement is carefully defined are clearly needed.

One limitation of this study was the small size of the cohort with Down syndrome. This was, however, the total number of patients with Down syndrome who

could be identified as having undergone CT during the 11 years of the study. Although the small sample size limited the precision of the estimated morphometric differences between the patient groups, the fact that statistical significance could be achieved despite the sample size indicates the strength of the evidence that the differences indeed exist. The large age span also was a concern, but the study design, which matched subjects on the basis of age (and sex and race) controlled for unanticipated effects that might have been introduced.

In summary, our results confirmed the findings from prenatal studies in which the iliac angle was shown to be larger in patients with Down syndrome, as compared with that in patients without Down syndrome. The results also suggest the potential usefulness of this measurement as a marker of aneuploidy. The iliac length measurement may also be useful in distinguishing between patients without and patients with Down syndrome, although perhaps not as was proposed in the prenatal study (4) of this index. These data suggest that the middle sacral level may be the optimal site for both measurements, because the greatest differences in these measurements between patients without and patients with Down syndrome occurred at this level. Prospective prenatal US investigations of iliac angle and iliac length measurements are needed at standardized transverse levels to help further clarify the clinical utility of the pelvic CT morphologic differences demonstrable between patients with and patients without Down syndrome.

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