Symphysis pubis width in the pediatric population: A computerized tomography study

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BACKGROUND: Defining pathologic widening of the pubic symphysis in the pediatric population continues to be a clinical challenge. The purpose of this study is to define a normal range of pubic symphyseal widths in various age and gender groups using axial computerized tomography (CT) scans.

METHODS: Axial CT images of 140 patients aged between 2 years and 15 years were obtained from our database of preexisting scans. Using a commercially available software package, the single image with the narrowest pubic symphyseal width was identified and measured. Patients were further stratified based on gender and by age into three groups: group A (age 2–5 years), group B (age 6–11 years), and group C (age 12–15 years).

RESULTS: The mean width ± 95% confidence interval for all cases was 4.59 mm ± 0.18 mm. The mean width for male and female patients was 4.86 mm ± 0.26 mm and 4.33 mm ± 0.24 mm, respectively. Based on the two-way analysis of variance, both age group and gender had a statistically significant effect. Post hoc testing demonstrated a statistically significant difference in mean symphyseal width between groups A and C ($p < 0.0001$) and groups B and C ($p = 0.0025$) but not between groups A and B ($p = 0.055$). When grouped by age, the mean male pubic symphyseal width was found to be 5.10 mm, 4.93 mm, and 4.45 mm, while the mean female width was found to be 4.94 mm, 4.33 mm, and 3.54 mm at 2 to 6 years, 7 to 11 years, and 12 to 15 years of age, respectively.

CONCLUSION: In the pediatric population, males seem to have a wider pubic symphysis than females of the same age group. In both males and females, pubic symphyseal width decreases during the transition from infancy toward skeletal maturity. (*J Trauma Acute Care Surg*. 2012;73: 923–927. Copyright © 2012 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Epidemiologic study, level III.

KEY WORDS: Pelvic fracture; symphysis; pediatric; orthopedic.

Injury to the symphysis pubis in the skeletally immature pelvis is difficult to identify radiographically.[1,2] The anatomic variation associated with skeletal growth and physeal maturation compromises the radiographic diagnosis of symphyseal disruption, and the lack of a contralateral joint or physis for comparison (a common technique in delineating pediatric fractures and dislocations) makes symphyseal injury particularly difficult to detect in children.[3] In the adult literature, the normal width of the symphysis pubis has been well described and injury to the pelvic ring correlated to the extent of the abnormality of the symphysis width.[4–6] Although the "normal" widths of the symphysis in the pediatric patient population at different stages of skeletal growth have been reported,[7–9] all values have been based on nonstandardized anteroposterior (AP) pelvic radiographs and nonvalidated methods for the measurement of the symphysis.

Recent literature has questioned the use of the AP pelvis for the diagnosis of pelvis trauma in the pediatric patient population, reporting high rates of misdiagnosis and inaccuracy when compared with computerized tomography (CT) scanning.[2,10–12] Open physes and variability in the epiphyses through growth can be easily confused for fractures and diastases, and vice versa. Furthermore, the anterior ring is often difficult to analyze on the AP pelvis because of pelvic malorientation with respect to the X-ray beam, contrast extravasation from injured viscera, and the unique fracture patterns (multifragmentary anterior ring injuries) common to the pediatric patient population[13–18] (Fig. 1). Not surprisingly, Guillamondegui et al.[2] showed that pelvic radiographs identified only 54% of all pediatric pelvic fractures and demonstrated a sensitivity of 75.5% and a negative predictive value of 79.4% for detecting symphyseal disruption when compared with the CT scanning.

At our high-volume, Level I trauma center, we have had difficulty diagnosing injury to the anterior pelvic ring with plain radiography in children and are highly reliant on CT scanning for the diagnosis of symphyseal disruption. To our knowledge, there has not been a study to describe the standard CT appearance of the uninjured pediatric pubic symphysis during skeletal growth despite the increasingly common clinical use of the CT scan as the "gold standard" for pelvic ring injury. The aim of this study is to describe a reference standard for normal pediatric symphyseal widths measured

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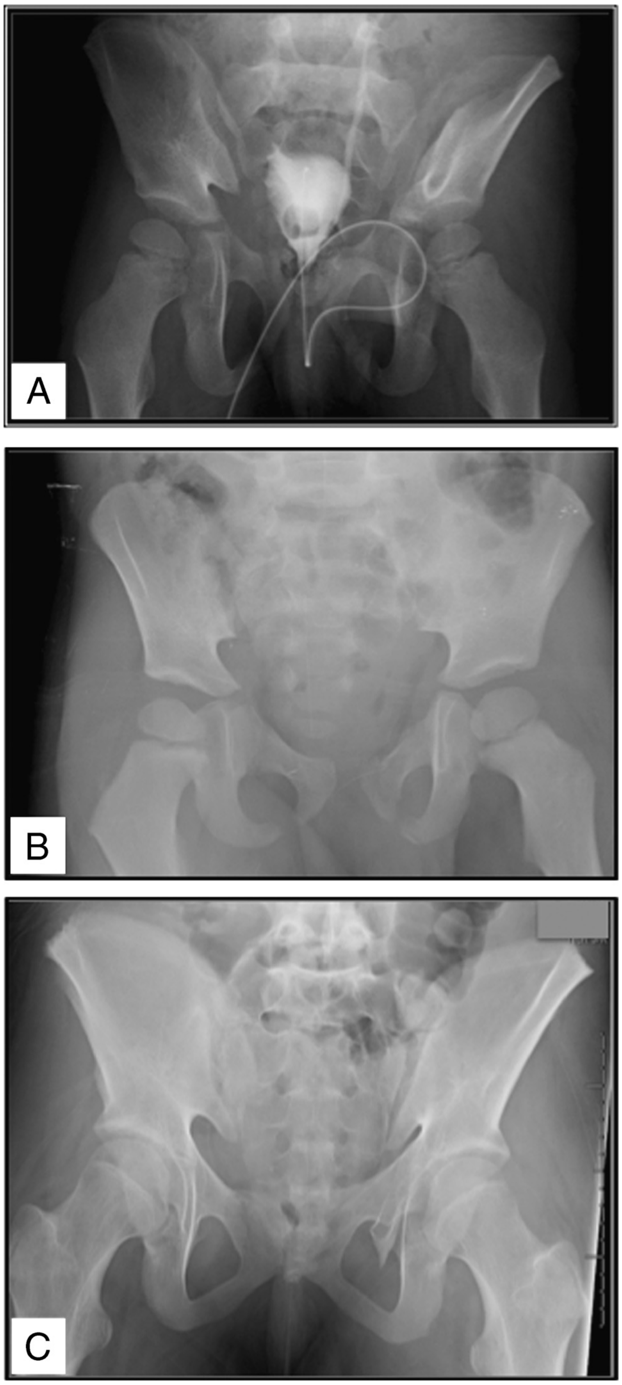

Figure 1. AP pelvic radiographs of three individual pediatric patients evaluated for pelvic fractures. Note the difficulty in evaluating the pubic symphysis in each case. (*A*) Patient has bladder contrast and bowel gas, a foley guide, and multiple ramus fractures obscuring the boarders of the symphysis. (*B*) Patient has multiple fractures of the rami, and close evaluation of the iliac wing contour and the obturator profiles demonstrates that this image was obtained obliquely such that measurements of the coronal plane structures will be distorted. (*C*) The film for patient was obtained with a cephalad tilt, thus it is more of an outlet image. Bowel gas and boney overlap of the sacrum and coccyx make measurement of the width of the symphysis very difficult.

from axial CT scans according to patient age and gender, as these values would be useful and more clinically relevant than a reference standard based on the AP pelvic radiograph. We hypothesized that CT measurements of symphyseal width would demonstrate an inverse relationship between age and width in the skeletally immature and that there would be a gender difference between average symphyseal width in age-matched subjects.

PATIENTS AND METHODS

In all, 140 patients aged 2 years to 15 years who had undergone CT scanning of the pelvis were identified from our institutional radiology database. Inclusion criteria consisted of patients aged 2 years to 15 years who had undergone CT scanning for a diagnosis other than for hip pain, had stored images with 1.3 mm axial slices from L5 to the most caudal point of the pelvis, and an official reading by a fellowship-trained pediatric radiologist that was notable for the absence of any congenital or traumatic abnormalities. Patients with spina bifida occulta at S1 were not excluded as we felt this would not affect the imaging of the symphysis pubis, and inclusion would enhance external validity of the results. Patients were excluded for motion or external artifact obscuring the image quality of the CT scans. Using a random sampling technique based on medical record numbers, five male and five female scans at each age meeting the inclusion criteria were selected. All portions of the study were approved by our Institutional Review Board.

The CT data of the study group were imported into a commercially available and validated software package (Mimics, Materialise, Ann Arbor, MI).[19] The software was used to threshold the axial two-dimensional images (Fig. 2) allowing bone and soft tissue to be segmented. The software's threshold function was applied uniformly to all scans to best delineate osseous structures. Using the thresholded images, the single axial image from the narrowest pubic symphyseal distance was determined, and using the two-dimensional measuring capability of the software, the narrowest pubic symphyseal width was measured (Fig. 3). In spite of the specialization of this software package, we ensured that the same measurements could be performed in any commercially available radiologic picture archiving and communication system.

Patients were placed into one of three groups based on previous categorization in the literature.[7] These groups included group A, 2 years to 6 years; group B, 7 years to 11 years; and group C, 12 years to 15 years.

Statistical Analysis

Inter- and intraobserver reliability analysis was performed using intraclass correlation coefficients (ICCs) for a total of 20 measurements performed by two observers at a minimum of 2 weeks apart using a commercially available software package (SPSS, Version 9; IBM, Chicago, IL). Data were analyzed using a commercially available statistical software packages (StatView; SAS Institute, Cary, NC). Means, standard deviations, and standard errors were determined for each age group and gender for all 140 patients. The data were analyzed using a two-way

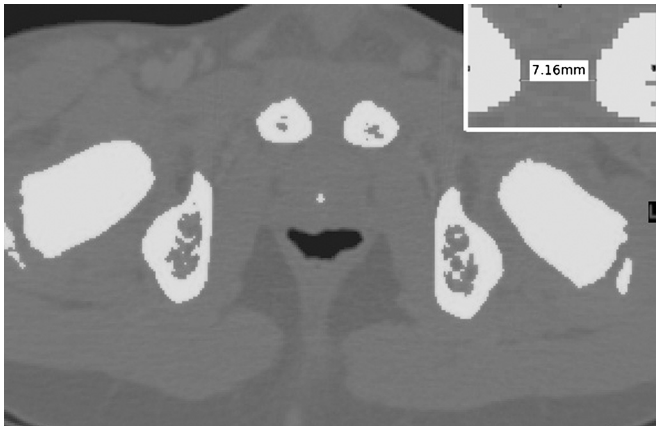

Figure 2. Axial CT scan image after segmentation with software. Pubic symphyseal width is measured as shown in upper right corner of image.

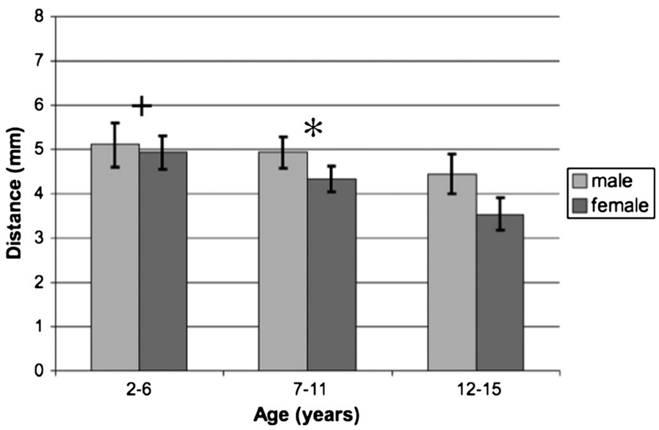

Figure 3. Pubic symphyseal width (mm) as a function of age group and gender (mean ± SD). Symbol (+) indicates significance between age groups A (2–6 years) and C (12–15 years) ($p < 0.001$) and symbol (*) indicates significance between age groups B (11–14 years) and C (12–15 years) ($p = 0.003$).

analysis of variance to determine the effect of age and gender on pubic symphyseal width. Statistical significance was set at $p = 0.05$. Post hoc testing between groups was performed using the Bonferroni/Dunn test.

RESULTS

The average pubic symphyseal width decreased with age, and this relationship was statistically significant (Table 1; Fig. 3). The mean width of the pubic symphysis ±95% confidence interval for all 140 patients was 4.59 mm ± 0.18 mm. The mean width for male patients was 4.86 mm ± 0.26 mm, which was wider than average female pubic symphyseal width found to be 4.33 mm ± 0.24 mm. The pubic symphyseal width of patients aged 2 years to 6 years (group A) was found to be 5.02 mm ± 0.32 mm, 7 years to 11 years (group B) 4.64 mm ± 0.24 mm, and 12 years to 15 years (group C) 4.00 mm ± 0.32 mm. Within each group, male symphysis pubis width was larger than that of females (Table 1; Fig. 2).

The range of widths stratified by age and gender are reported in Table 2. There were no male widths greater than 9.18 mm and no female widths greater than 7.93 mm. The maximum widths decreased with such that the maximum male widths were 9.18 mm, 7.93 mm, and 6.04 mm for groups A, B, and C, respectively, and the maximum female widths were 7.93 mm, 5.63 mm, and 5.35 mm for groups A, B, and C, respectively.

Using two-way analysis of variance results, significant effects for both gender ($p = 0.001$) and age ($p < 0.0001$) were noted (Tables 1 and 2). Using the Bonferroni/Dunn post hoc test, statistical significance was found between the youngest and oldest age groups (groups A and C) ($p < 0.0001$) and also between groups B and C ($p = 0.0025$). Statistical significance was not found between the two youngest age groups, groups A and B ($p = 0.055$).

ICCs revealed a high degree of both intra- and interobserver reliability. ICCs were 0.8681 and 0.8641 for observers 1 and 2, respectively. ICCs were 0.8903 and 0.8647 for sessions 1 and 2, respectively.

DISCUSSION

This retrospectively reviewed a cohort of skeletally immature patients with normal osseous pelvic CT scans to identify reference values of the normal symphyseal width in the uninjured patient according to age and gender. By measuring the CT images with 1.3 mm sections and validated software, this measurement protocol is able to precisely measure the minimum symphyseal width on the axial sections. The findings of this study demonstrate that the width of the pubic symphysis decreases as patients become skeletally mature and this phenomenon is most pronounced at the time of puberty (Figs. 3 and 4). Furthermore, in the pediatric population, pubic symphyseal width differs significantly between males and females within the same age group (Table 1). In this study group, no patient had a normal symphyseal width greater than 9.20 mm or narrower than 2.2 mm, strongly supporting further evaluation for any patient with a measured width by axial CT outside this range. We report the mean widths and ranges for each patient age and gender and recommend these as reference values in the clinical evaluation of potential symphyseal disruption for a given patient's demographics.

TABLE 1. Pubic Symphyseal Width by Age and Gender

AGE (group)	Sex (n)	MEAN ± SD (mm)	Range (mm)	95% C.I.
2–6 yr (A)	Male (25)	5.10 ± 1.28	3.04 – 9.18	0.52
	Female (25)	4.94 ± 0.98	3.39 – 7.93	0.39
7–11 yr (B)	Male (25)	4.93 ± 0.89	2.76 – 6.24	0.36
	Female (25)	4.33 ± 0.74	2.78 – 5.63	0.29
12–15 yr (C)	Male (20)	4.45 ± 1.04	2.50 – 6.04	0.46
	Female (20)	3.54 ± 0.84	2.17 – 5.35	0.38

SD, standard deviation; CI, confidence interval.

TABLE 2. Post Hoc Bonferroni/Dunn Analysis of Variance Between Each of the Three Groups

Source of Variation Age (group)	Mean Difference	Critical Difference	p
2–6 yr (A) vs. 12–15 yr (C)	−1.025	0.503	<0.0001
7–11 yr (B) vs. 12–15 yr (C)	−0.636	0.503	0.0027
2–6 yr (A) vs. 7–11 yr (B)	0.389	0.474	0.0488

In spite of the use of a validated measurement technique and our access to a large database of CT scans with a stratified sampling technique, our study has a number of important limitations. As a retrospective cohort observational study design, inherent bias based is possible. We did not evaluate the clinical diagnoses leading to CT evaluation, thus some patients included in the study may have had pathologically increased symphseal widths for nontraumatic reasons. This would lead to an inappropriate reporting of ranges and averages for the study population and compromise the validity of our findings. Although our results indicated a statistically significant difference in pubic symphyseal width between groups, the mean widths for several age groups had large standard deviations and wide confidence intervals indicating variation in the width. We therefore report the ranges of normal and recommend correlation with clinical findings in interpreting a given symphyseal width compared with the population mean.

Despite these limitations, our study has strengths and important implications. Although previous studies have attempted to identify ranges of symphyseal width based on age,[7–9] these reports relied on nonstandardized, plain radiographic projections of the symphysis and thus have limited application in the clinical setting. Recent evidence demonstrates that the AP pelvis has poor test performance in the evaluation of pelvis fractures in pediatric and adult patients.[2,10–12] As a result, there has been a shift toward the use of CT as the gold standard for diagnosis of pediatric pelvic trauma. Our experience has mirrored that of the available literature and has been notable for a high rate of missed injuries in the anterior ring of skeletally immature patients. The AP pelvis of pediatric trauma patients commonly has bladder contrast masking the anterior ring skeletal anatomy, and it can be very difficult to distinguish between multiple ramus fractures and symphyseal disruption. This is important as the later typically requires surgery, while ramus fractures rarely require surgical intervention.[4–6] Furthermore, it is difficult to appropriately orient the X-ray beam in trauma patients. Tannast et al.[18] showed that the obliquity with which plain views are obtained clearly influences the measurement of radiographic relationships such as the diameter of frontal plane spaces such as the symphsis. A film that is off-axis can create a radiographic symphyseal width that is larger or smaller than the anatomic measurement. The CT scan has replaced the AP pelvis in the diagnosis of injury in the pediatric pelvis and is much more sensitive for injury providing the impetus for this study.

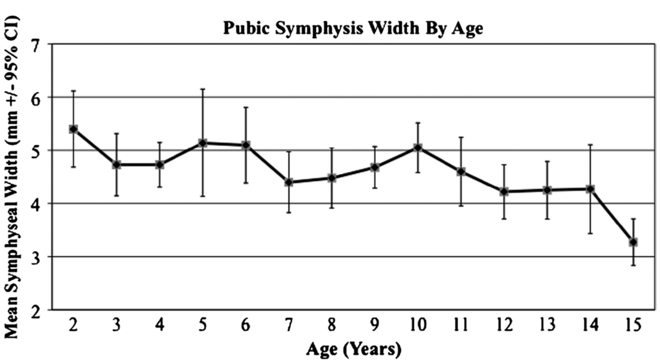

Figure 4. Pubic symphyseal width (mm) as a function of age (years) (mean ± 95% confidence interval).

Consistent with previous investigations, we found that the symphyseal width deceased with age. Patel and Chapman[9] evaluated 888 patients from birth to 16 years of age. They demonstrated a general trend of a decreased symphyseal width with age and a mean global width of 7.05 mm. This mean is larger than the global mean of 4.59 mm ± 0.18 mm in our series. This may be reflective of the stratified sampling method of our series, the equal distribution of patient ages across the study group, and their inclusion of the 0 year to 2-year-old children (which have the widest symphysis and would therefore increase the mean cohort width). In a review of 200 AP pelvic radiographs, Muecke and Currarino[8] found that patients less than 2 years of age had symphyseal widths varying between 5 mm and 9 mm while children aged 2 years to 13 years had values varying between 4 mm and 8 mm. This study lacked a statistical analysis of the difference between these two groups and used noncalibrated images. In spite of this, their results demonstrate a trend toward a decrease in symphyseal width with age. Furthermore, the maximum width identified in their study was 9.0 mm, very close to that of our study.

In a more recent study by McAlister et al.,[7] AP radiographs were used to evaluate 238 patients aged 2 years to 14 years. They found a mean width of 6.8 mm with a standard deviation of 1.6 mm. Further evaluation was suggested in patients with pubic symphyseal widths less than 5.2 mm or greater than 8.4 mm. This study was the only prior investigation to use an electronic tool to measure the radiographs, but an analysis of the accuracy and precision of their method was not described. Furthermore, the authors did not comment on the standards for inclusion of the pelvic radiographs in the study, indicating that images were obtained without standardization of the image acquisition protocol. The reported level of agreement of three observers was "moderate," demonstrating the lack of precision associated with the use of nonstandardized plain films. They found a global mean higher than that determined by our data, again reflecting the difference in imaging modality and measurement technique as well as the inclusion of slightly older patients (who had narrower symphyses) in our study. However, the maximum width in their study was close to that same value in both our study and in that of Muecke and Currarino.[8]

In conclusion, this investigation of the normal symphyseal widths of skeletally immature patients demonstrated that width as measured from the CT axial scans decreases with age. The maximum symphyseal width of 9.2 mm in this study is consistent with previously reported values. Our results provide a range of presumably normal symphyseal widths stratified by age groups and gender. We believe these reference standards to be more accurate and precise than previous information in the literature as they are based on validated methods and software analysis of CT scans, the gold standard imaging modality for diagnosis of symphyseal disruptions. Based on the results of this study, we recommend a high index of suspicion for symphyseal injury in patients with radiographic symphyseal widths outside the ranges reported in this study.

DISCLOSURE

The authors declare no conflicts of interest.

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