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Multidetector Computed Tomographic Evaluation of the Normal Characteristics of the Thymus in the Pediatric Population

ORIGINAL ARTICLE

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ABSTRACT

Objectives: The objective of the present study was to determine the morphologic features and measurements of the normal thymus on contrast-enhanced multidetector computed tomography (MDCT) in subjects from the newborn period up to 18 years of age.

Materials and Methods: The MDCT scans obtained from 464 children with a mean age ± SD of 8.43 ± 5.60 years were retrospectively re-evaluated. The shape, margins, side predominance, density, and measurements of the thymic gland were defined for each age group.

Results: A triangular thymic shape with a middle location and straight lateral contours were the most frequently seen morphologic features in children. The mean anteroposterior and transverse diameter of the thymus was 17.32 ± 4.58 and 29.99 ± 11.42 mm, respectively. The mean values for the width and thickness were 20.66 ± 5.36 and 15.15 ± 6.76 mm for the right thymic lobe, respectively; and 26.14 ± 7.85 and 14.91 ± 5.51 mm for the left, respectively. The transverse diameter of the thymus and thymic lobe dimensions decreased significantly with age, however, the anteroposterior diameter of the thymus was not significantly associated with age. Girls had higher mean thymic attenuation values compared to boys, however, this gender difference was not statistically significant (63.8 ± 22.4 HU vs. 60.1 ± 25.3, p = 0.164).

Conclusion: Our study provides a better understanding of the normal thymic appearances in children that can aid in accurate diagnosis and avoid unnecessary, costly, and invasive interventions.

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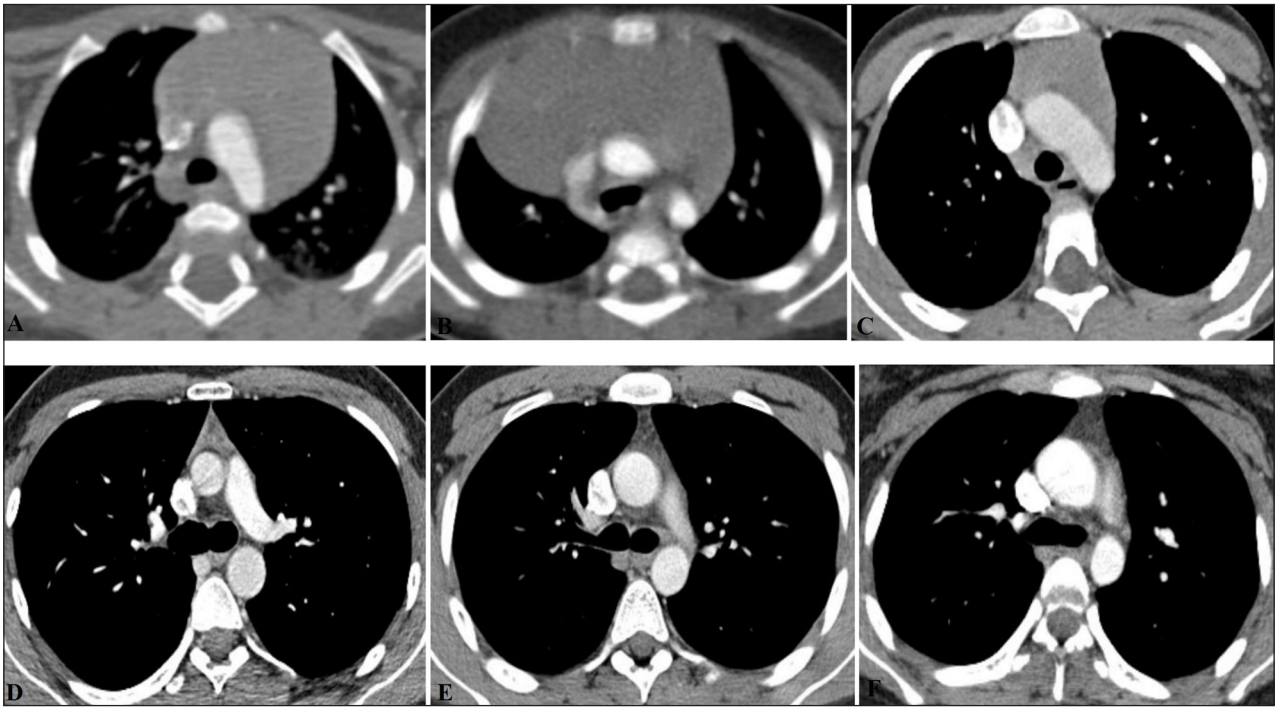

Figure 1 The axial thoracic contrast-enhanced computed tomography images present the morphologic features of the thymus in children. **(A)** 1 year old girl; round-oval shape; biconvex margins; predominantly left-sided location; Score 3, mainly soft-tissue attenuated thymus. **(B)** 4 months old boy; round-oval shape; biconvex margins; predominantly right-sided location; Score 3, mainly soft-tissue attenuated thymus. **(C)** 5 years old boy; quadrilateral shape; mixed (right straight, left convex) margins; middle location; Score 3, mainly soft-tissue attenuated thymus. **(D)** 15 years old boy; triangular shape; straight margins; middle location; Score 2, nearly half fatty and half soft-tissue attenuated thymus. An example of a manually delineated free-hand region of interest (ROI) for measuring the CT attenuation value is presented. **(E)** 17 years old boy; triangular shape; straight margins; middle location; Score 1, mainly fatty thymus. **(F)** 18 years old boy; triangular shape; biconcave margins; middle location; Score 0, complete fatty thymus.

1E); Score 2, nearly fifty percent of fatty and fifty percent of the soft-tissue attenuated thymus (Figure 1D); and Score 3, mainly soft-tissue attenuated thymus (Figure 1A, B, C) [7].

The mean thymic CT attenuation values in Hounsfield Units (HU) were measured on axial images using a manually delineated free-hand region of interest (ROI) covering the maximum area of the gland and avoiding the surrounding mediastinal fat, large blood vessels, motion artifacts, and partial volume effects (Figure 1D) [8, 9].

The measurements were performed, as previously described, on a single axial CT image showing the largest area of the thymic gland [5, 7, 10]. The maximum anteroposterior (AP) diameter of the thymus was measured at the midline at its thickest part dividing the gland into the right and left lobes. The maximum transverse diameter of the thymus was determined by measuring the widest distance between the outer margins of the thymic lobes. The maximal thymic lobe width was estimated by measuring the longest distance from the midline to the farthest lateral margin of each lobe. The maximal lobe thickness was measured perpendicular to the long axis of each lobe (Figure 2).

The image analysis was performed by a single European Board of Radiology – certified radiologist who was blinded to the age and gender of the patients.

STATISTICAL ANALYSIS

Distributions of continuous variables were assessed for normality using the Skewness-Kurtosis test and Kolmogorov-Smirnov test. Normally distributed data were presented as mean ± standard deviation (SD) and compared by one-way analysis of variance (ANOVA) test followed by post hoc analyses. Skewed distributed data were expressed as median [interquartile range (IQR) 25 – 75] and analyzed by the Wilcoxon rank-sum test and Kruskal-Wallice test. Categorical variables were compared by the Chi-square test and summarized using frequencies and percentages.

After logarithmic transformation of non-normal distributed data, linear regression analyses adjusted for age and gender were performed to assess the relationship between thymic measurements and thymic CT attenuation values over time and age groups.

Data were analyzed statistically using SPSS software, version 20.0 (SPSS Inc., Chicago, IL). P-values less than 0.05 were regarded as statistically significant.

RESULTS

DEMOGRAPHIC DATA

The study group included 266 (57.3%) boys and 198 (42.7%) girls with a mean age ± SD of 8.43 ± 5.60 years

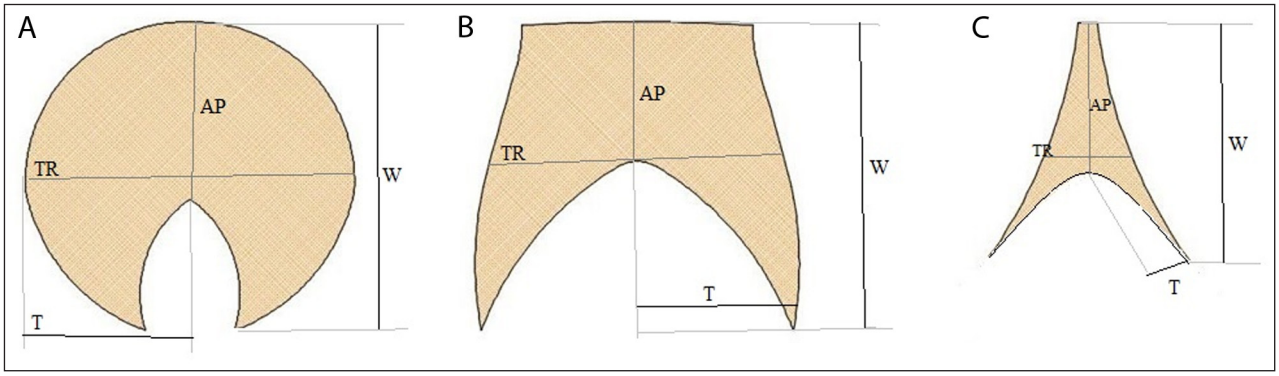

Figure 2 The graph shows the measurements of the maximum anteroposterior (AP) and transverse (TR) diameter of the thymus; maximum width (W) and thickness (T) of the thymic lobes in the **(A)** round-oval, **(B)** quadrilateral, and **(C)** triangular thymic shape.

(age range 0 – 18 years). Children were stratified into six groups according to their age: Group 1 (0 – 12 months, n = 24); Group 2 (1 – 3 years, n = 94); Group 3 (4 – 6 years, n = 83); Group 4 (7 – 10 years, n = 72); Group 5 (11 – 14 years, n = 104); and Group 6 (15 – 18 years, n = 87). The age groups were chosen according to the classification and definition of medical subject headings (MeSH) (i.e., infants, toddlers, preschool children, primary school-age children, secondary school-age children, and adolescents).

MORPHOLOGIC FEATURES OF THE THYMUS ON CT

A quadrilateral shaped thymus (201/464, 43.3%) was the most frequently seen morphologic feature on CT in children, followed by triangular (169/464, 36.4%) and round-oval (94/464, 20.3%). A round-oval thymus was more common in younger children with a mean age ± SD of 3.02 ± 3.23 years. A triangular thymus was more often seen in older children aged 11 years and above. These age-related differences in thymic shape proved to be statistically significant ($p < 0.0001$).

The majority of children had straight (228/464, 49.1%), followed by biconvex (109/464, 23.5%), and mixed (106/464, 22.8%) thymic margins. The biconcave (21/464, 4.6%) borders were less commonly seen. Among the mixed thymic margins, 50% (53/106) of the study group had a combination of right straight-left convex and 33% (35/106) had right convex – left straight lateral contours. The thymus with biconvex margins was most commonly found in small children aged between 0 and 3 years. The thymus with straight contours was observed in nearly all subjects aged 15 years and above. The differences in thymic margins among age groups were statistically significant ($p = 0.001$).

The thymus was located at the midline in 266 (57.3%) and showed a predominance on the left side in 134 (28.9%), and on the right side in 64 (13.8%) children. The midline position of the thymus was more frequent among children older than 11 years of age. The right-sided thymus was common in infants aged 0–12 months. The age-related differences in the thymic side were statistically significant ($p < 0.0001$).

The shape, margins, and the side predominance of the thymus did not show differences among gender ($p = 0.958$, $p = 0.059$, $p = 0.101$, respectively).

The morphologic features of the thymus according to age groups are summarized in Table 1.

THYMIC ATTENUATION ASSESSMENT

The estimation of thymic attenuation was made via subjective and objective assessment. The majority of children in our study had a mainly soft-tissue attenuated thymus (Score 3) (391/464, 84.3%), followed by half fatty and half soft-tissue attenuated (Score 2) (56/464, 12.1%) and mainly fatty thymus (Score 1) (14/464, 3%). The complete fatty replacement of the thymus (Score 0) was observed in only 3 (0.6%) subjects. The thymic attenuation score did not show a significant gender difference ($p = 0.271$).

The mean thymic CT attenuation values were 61.7 ± 24.2 (range, – 40.2 – 104.6) HU. In general, girls had higher mean thymic attenuation values (63.8 ± 22.4 HU) compared to boys (60.1 ± 25.3 HU), and this gender difference was not statistically significant ($p = 0.164$). There was a good correlation between subjective thymic scoring and objective measurements of the CT attenuation values [$F(1, 462) = 665{,}179$, $p < 0.0001$, $R^2 = 0.590$]. With increasing age, the fatty content of the thymus increased, while the thymic CT attenuation values diminished significantly ($p = 0.002$).

The distribution of the thymic density according to age is described in Table 2.

THYMIC GLAND DIMENSIONS

The mean anteroposterior (AP) and transverse diameter of the thymus was 17.32 ± 4.58 (range, 6.22 – 35.45) and 29.99 ± 11.42 (range, 7.65 – 71.70) mm, respectively. The mean values for the width and thickness were 20.66 ± 5.36 (range, 5.45 – 42.06) and 15.15 ± 6.76 (range, 1.83 – 38.47) mm for the right thymic lobe, respectively; and 26.14 ± 7.85 (range, 6.00 – 55.27) and 14.91 ± 5.51 (range, 3.50 – 40.00) mm for the left, respectively.

Although insignificant, the width of the left thymic lobe showed dominance over the right lobe in both