A detailed look in radioanatomical aspects of ligamentum arteriosum calcification in pediatric population

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SUMMARY

After birth, ductus arteriosus forms ligamentum arteriosum and sometimes can be calcified. Ligamentum arteriosum calcification can be seen as subtle-punctate or coarse-linear between pulmonary artery and the aorta in the non-contrast computed tomography (CT) images, and between the pulmonary conus and the aortic knob in the chest radiography. In this study, we aim to estimate the prevalence of ligamentum arteriosum calcification on non-contrast CT and chest radiography in a pediatric population. Patients aged 0-18 years, who underwent non- contrast CT and chest radiography at Department of Radiology between March 1, 2020 and October 31, 2021 were evaluated retrospectively. It was examined whether there was ligamentum arteriosum calcification in non-contrast CT and chest radiography. If there is calcification, it was recommended as subtle-punctate or coarse-linear, and information was documented by grouping the patients' age. If ligamentum arteriosum calcification was present, it was divided morphologically into two groups (subtle-punctate and coarse-linear) and classified according to the age groups. The research population consisted of 1003 patients. Non-contrast CT revealed calcification in 25.5% of patients (n=256). 11.3% of patients had subtle-punctate calcification, and 14.3% had coarse-linear calcification. Radiography had a 1.7% (n:17) detection rate for calcification. Ligamentum arteriosum calcification is a common finding in all age groups in the pediatric population. When reporting pediatric CT studies, radiologists should be able to distinguish ligamentum arteriosum calcification from other pathological and anatomical conditions and accept it as a normal finding in order to avoid unnecessary further investigations.

Key words: Ligamentum arteriosum – Non-contrast computed tomography – Chest radiography – Calcification – Pediatric population

INTRODUCTION

The ductus arteriosus is an important structure that connects the pulmonary artery to the aorta

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and plays a role in the right-to-left shunt of blood passing through the lungs during the fetal period. After birth, the ductus arteriosus closes and forms the ligamentum arteriosum. Sometimes the ligamentum arteriosum can be calcified (Currarino and Jackson Jr, 1970; Murphy, 2005; Ampanozi et al., 2010; Keet et al., 2018). On computed tomography (CT) in adults, the ligamentum arteriosum calcification can be seen subtle-punctate or coarse-linear between the proximal descending aorta and the pulmonary artery superior (Ampanozi et al., 2010). Calcification of the ligamentum arteriosum in adults is considered a benign formation and calcified in the mediastinum is different from other anatomical structures (calcified pulmonary artery seen in patients with long-standing pulmonary hypertension, aortic coarctation, ductus arteriosus aneurysm) and pathological conditions (granulomatous infections and neoplastic diseases such as neuroblastoma, teratoma, treated lymphoma). The distinction is made by the precise anatomical location of the calcification, the absence of associated soft tissue mass, and the absence of other signs of mediastinal or congenital heart disease (including indirect manifestations of patent ductus arteriosus) (Bisceglia and Donaldson, 1991; Ampanozi et al., 2010).

Although ligamentum arteriosum calcification is a well-known phenomenon among experienced pediatric radiologists, there are few publications in the medical literature to date, all of which have different findings. General radiologists may also have a greater obligation to report on routine pediatric imaging given the rising demand for pediatric imaging across the country and the dearth of specialist services for reporting. In order to avoid needless additional testing and incorrect diagnoses, the ability to recognize pathological formation and normal anatomical variation will be essential (Halliday et al., 2016).

The aim of our study is to define the frequency and types of ligamentum arteriosum calcification seen in the pediatric population. Our aims are to facilitate accurate and effective diagnosis for radiologists and to provide information about ligamentum arteriosum calcification to other physicians.

MATERIALS AND METHODS

The local institutional review board approved this study, and as a result of retrospective nature, informed consent was waived (Desicion number: E-21142744-804.99-96230).

At the Radiology Department of Erzincan Binali Yıldırım University, Mengücek Gazi Training and Research Hospital, 1028 patients, ages 0 to 18, who underwent non-contrast thorax CT and posteroanterior chest radiography, were retrospec-

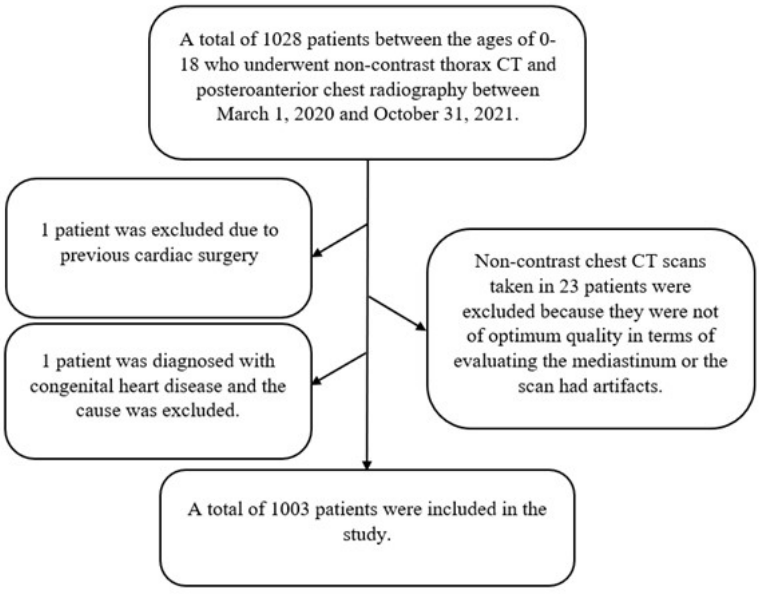

Fig. 1.- Diagram showing study population.

tively scanned between March 1, 2020, and October 31, 2021. Among these patients, one patient was excluded because of cardiac surgery, one patient was diagnosed with congenital heart disease, and 23 patients were excluded because the uncontrasted thorax CT scan was not of optimum quality in terms of evaluating the mediastinum or the examination was artifact. The study involved 1003 patients in total, with 548 males (54.6%) and 455 females (45.4%) (Fig. 1).

With no contrast, a 16-section multi-detector computed tomography machine (Siemens Somatom, Forchheim, Germany) was used to examine all of the study participants. The following technical specifications were used in the CT machine: pitch was 0.8, rotation time was 0.6 seconds, slice thickness was 1.5 mm, tube voltage was 130 kVp, automatic tube current modulation was 70 mAs.

Using the Siemens Somatom Sensation-Syngo. via software program from the PACS (Picture Archiving Communication System) archive, evaluation of images in the axial, coronal, and sagittal planes was performed. To accurately determine the location and presence of ligamentum arteriosum calcification, evaluation was performed using multiplanar reconstruction techniques on non-contrast thorax CT using both standard mediastinal/soft tissue window settings and bone window settings.

The evaluation was carried out by two radiologists with 4 years and 10 years of radiology experience, and the final decision about the presence and the form of calcification of each patient was noted by common consensus. For each patient, the presence and the form of calcification were decided by using all of axial, coronal and sagittal CT images. Presence of calcification was defined as the detection of any calcification between the superior pulmonary artery and the proximal descending aorta. The calcifications were divided into two morphological groups; while linear and amorphous shaped calcifications were called coarse- linear (Fig. 2), other calcifications were called subtle-punctate (Fig. 3).

All the data was classified according to age groups (0-18 years, 18 age groups, one group for each year of age).

In addition, posteroanterior chest radiographs of the cases were also evaluated. Evaluators reviewed chest radiographs and CT images in a double-blind manner. They did not have information about the CT images of the cases whose chest radiographs were evaluated. The presence/absence of calcification was noted by looking at the chest radiographs, and no comment was made about the morphological structure. The presence of calcification on chest radiographies was also decided with consensus.

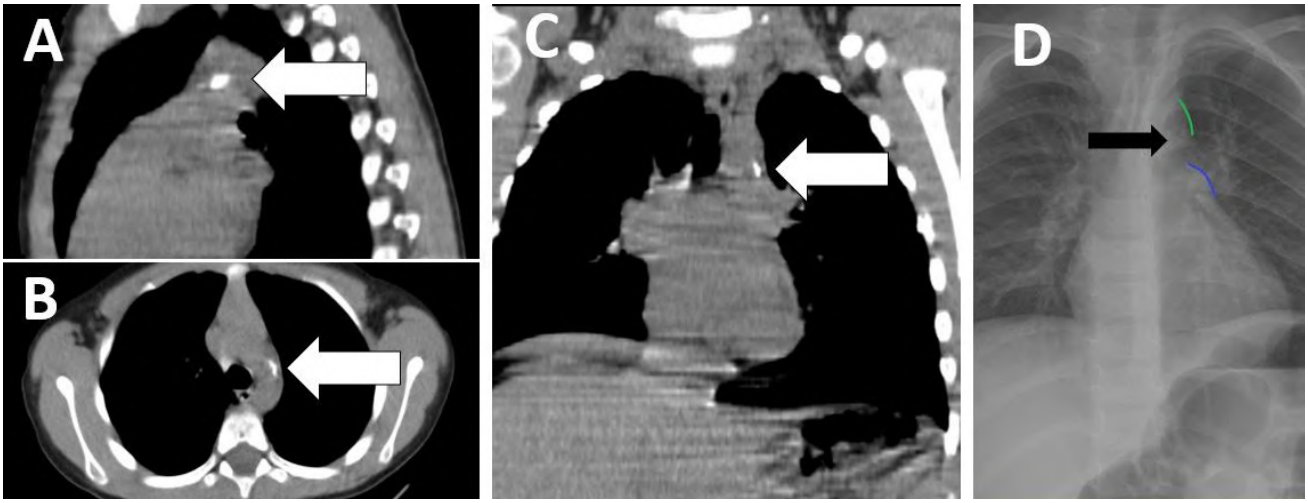

Fig. 2.- Demonstrating coarse-linear calcification of the ligamentum arteriosum on non-contrast thorax CT and chest radiography; In the sagittal (**A**), axial (**B**), and coronal (**C**) sections of the non-contrast thorax CT of a 3-year-and-11-month-old male patient, coarse-linear calcification (white arrows) is visible between the proximal descending aorta and the pulmonary artery. On the radiograph of the same patient (**D**), millimetric opacity (black arrow) is observed at the level of the 5th costochondral junction, between the aortic knob (green line) and pulmonary conus (blue line), and it corresponds to the calcification of the ligamentum arteriosum between the pulmonary artery and the aorta described in the CT images.

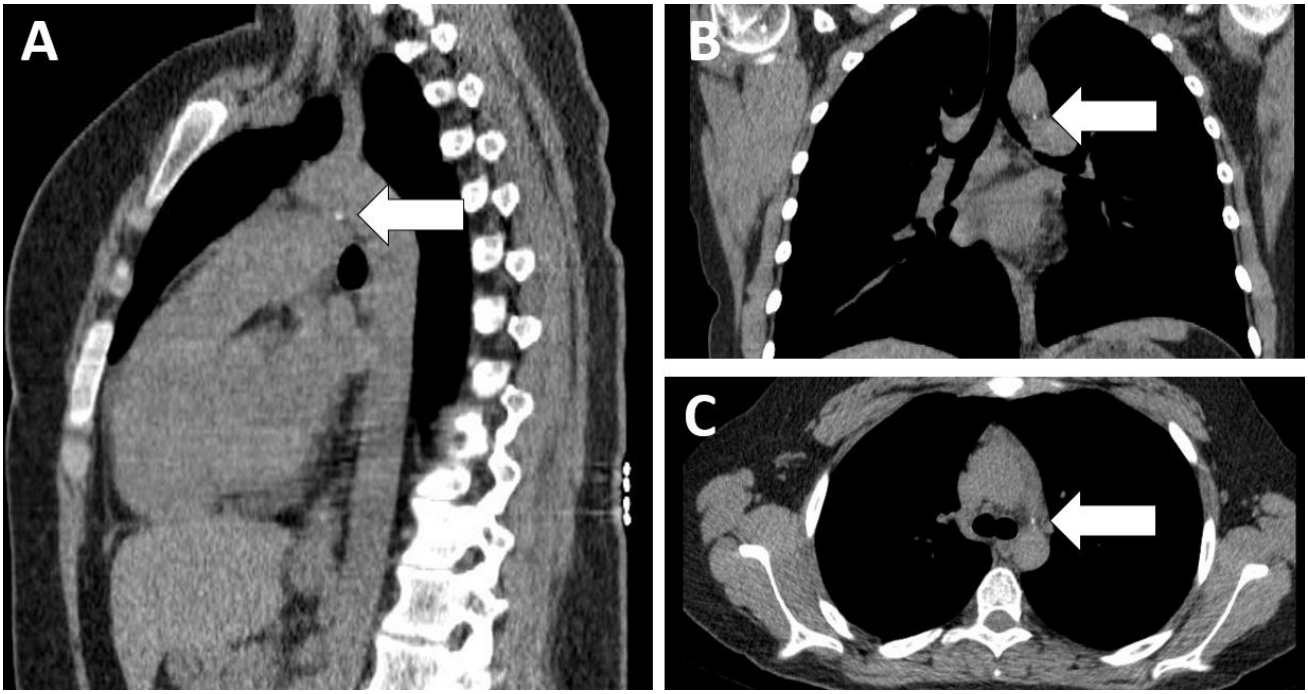

Fig. 3.- Demonstrating subtle-punctate calcification of the ligamentum arteriosum on non-contrast thorax CT; In the sagittal (**A**), coronal (**B**), and axial (**C**) sections of the unenhanced thorax CT of a 14 years and 7 months old female patient, subtle-punctate calcification (white arrows) is visible between the proximal descending aorta and the pulmonary artery.

Final data regarding the presence and morphology of calcification were determined using CT images.

Statistical analysis

Statistical analysis was performed using the IBM SPSS v20.0 (IBM Corp., Armonk, NY, USA) package program. The normal distribution of data was evaluated using the Kolmogorov-Smirnov test. Numerical with non-normal distribution were expressed as the median (min-max). The categorical variables were expressed as numbers and percentages. For comparisons between age groups, Mann-Whitney *U* test was used. Chi-square, Yates correction and Fischer tests were used to compare the rate of presence of calcification. The predictive value of age in terms of calcification presence was determined by Roc Curve analysis and Youden index method; $p < 0.05$ was regarded as statistically significant.

RESULTS

The study population consisted of 1003 patients, 548 males (54.6%) and 455 females (45.4%). The median age of the patients was 135 months (range: 3-215 months). The rate of patients with calcification on CT was 25.5% (n:256). Within these 256 patients, 113 calcifications were classified as subtle-punctate (11.3%, 113/1003); whereas 143 were coarse- linear (14.3%, 143/1003). The rate of calcification detected with chest radiography was 1.7% (17/1003). These results are shown in Table 1.

The presence of calcification did not differ significantly by gender (p=0.479). The median age was lower in those with calcifications than in those without (118 vs 139 months; p=0.013). While ligamentum arteriosum calcification is most commonly seen in the 8-to-9-age range, it was at least detected in the 0-to-1-year age range, however the rates of calcification presence did not show a statistically significant difference according to age groups (p=0.065). These results are shown in Table 2 and Fig. 4.

Calcification was also detected on chest radiography in 6.6% (17/256) of those with calcification detected on CT. In patients without calcification on CT, also no calcification was found on chest radiography. These results are shown in table 2. In those with subtle-punctate calcification on CT, no calcification was found on chest radiography. The cut-off value of age in terms of calcification presence was found to be <139 months with 61.3% sensitivity and 50.9% specificity.

Table 1. Demographic data and presence of calcification.

Variables	Population number (n=1003)
Gender	**n (%)**
Male	548(54.6)
Female	455(45.4)
Age groups (in months)	**n (%)**
0-12	10(1.0)
12-24	50(5.0)
24-36	52(5.2)
36-48	47(4.7)
48-60	37(3.7)
60-72	50(5.0)
72-84	49(4.9)
84-96	49(4.9)
96-108	36(3.6)
108-120	51(5.1)
120-132	61(6.1)
132-144	66(6.6)
144-156	54(5.4)
156-168	57(5.7)
168-180	67(6.7)
180-192	83(8,3)
192-204	101(10.1)
204-216	83(8.3)
Calcification on unenhanced CT	**n (%)**
Not present	747(74.5)
Present	256(25.5)
Subtle-Punctate	113(11.3)
Coarse-Linear	143(14.3)
Calcification on radiography	**n (%)**
Not present	986(98.3)
Present	17(1.7)

CT: Computed tomography, n: Number, %: Percentage

Table 2. Distribution of demographic and clinical departments according to the presence of calcification.

Variables	Calcification		p
	Not present n=747	Present n=256	
Gender			
Male	413(55.3)	135(52.7)	0.479
Female	334(44.7)	121(47.3)	
Age (in months)	**median (min-max)**	**median (min-max)**	
	139(3-215)	118(3-215)	0.013*
Age groups (in months)	**n**	**n**	
0-12	9	1	0.065
12-24	40	10	
24-36	36	16	
36-48	36	11	
48-60	23	14	
60-72	31	19	
72-84	33	16	
84-96	35	14	
96-108	21	15	
108-120	38	13	
120-132	43	18	
132-144	49	17	
144-156	45	9	
156-168	40	17	
168-180	57	10	
180-192	65	18	
192-204	81	20	
204-216	65	18	
Calcification on radiography	**n(%)**		
Not present	747(100.0)	239(93.4)	<0.001*
Present	-	17(6.6)	

n: Number, %: Percentages, min: Minimum, max: Maximum, *: Indicates statistical significance.

DISCUSSION

The main purpose of this study is to determine the frequency and pattern of ligamentum arteriosum calcification in the pediatric population. According to the data of our study, the frequency of ligamentum arteriosum calcification in the pediatric population was 25.5%. The presence of calcification did not differ significantly by gender. The rates of calcification presence did not show a statistically significant difference according to age groups.

Kaushik et al. (2004) suggested that the cambering of the ductus arteriosus, which is known as a normal formation by the pediatric radiologist, is actually a benign and self-limiting ductus arteriosus aneurysm, and that calcification of the ligamentum arteriosum results from the regression of the thrombus within the aneurysm; this was supported by Slovis and Berdon (2004).

The frequency of ligamentum arteriosum calcification of our population is slightly lower than

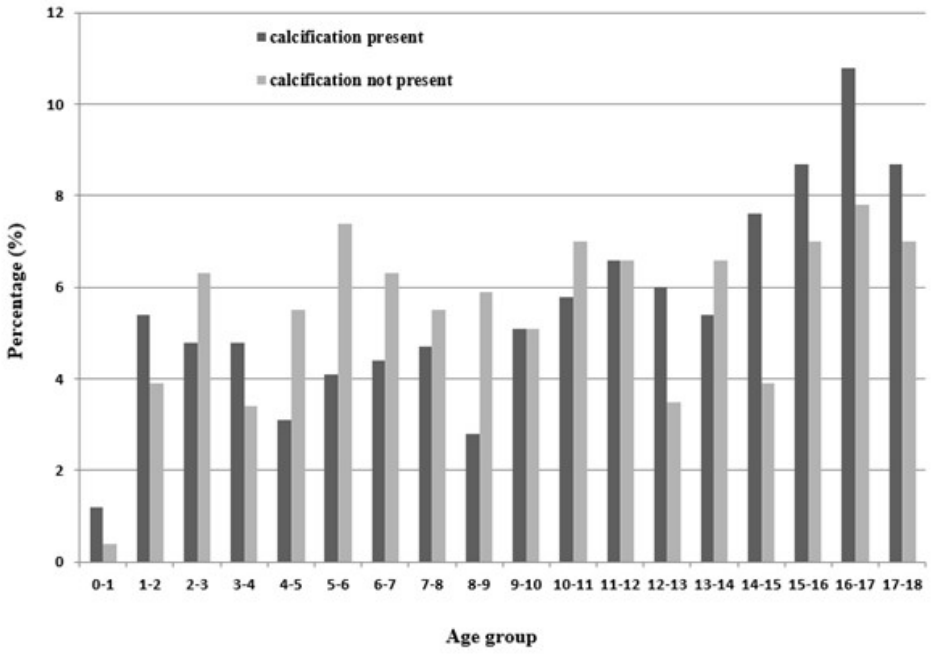

Fig. 4.- Calcification distributions in age groups.

Davendralingam et al. (2021) (Our data: %25.6 vs 30.5%). The possible reason for the mentioned difference can be explained with population characteristics: Davendralingam et al. (2021) studied with postmortem CTs in pediatric population, so that they can easily use thinner sections (0.7 mm sections), where as we used 1.5 mm sections. Thinner sections are especially useful in the detection of subtle-punctate calcifications. In addition, due to the fact that the patient group was in the postmortem period, they eliminated the respiratory and motion artifacts that may occur in CT scans and increased the sensitivity of the study. Similarly with Davendralingam et al. (2021), Proisy et al. (2015) also studied with postmortem pediatric cases, however they found a higher calcification rate (60.9%) in comparison with both the results in Davendralingam et al. (2021) and in ours. This situation can be explained by the population number . Proisy et al. (2015) had the lowest population number. When Davendralingam et al. (2021) and our study are evaluated together, it is seen that the frequency of calcification detection decreases as the population size increases.

In addition to studies conducted with postmortem cases, there are also publications involving living pediatric patients. Bisceglia and Donaldson (1991) found the rate of calcification as 13.2% in their study using 5-10 mm thick CT images, whereas Hong et al. (2012) defined this rate as 37.8% in their study performed with 3-5 mm thick CT images. Our rate falls between the rates in the mentioned publications. The differences between the mentioned publications and our results can basically be explained by population numbers. Our study constitutes the widest-ranging publication in the literature with a population of 1003 participants.

In the study of Davendralingam et al. (2021), the rate of calcification detection in pediatric radiography was 1.6%; in the study of Hong et al. (2012), this rate was 3.6%, and it was 1.7% in our study. Similar to the CT-based studies, these differences also can be attributed to the population numbers. Beluffi et al. (1998) reported a lower rate of 0.1% in their study, although they performed their study with film-screen images. Both our results and the results of the above-mentioned studies were acquired from digital radiographic images. Improvements in radiographic imaging techniques may have contributed to the better detection rate of ligamentum arteriosum calcifications.

In the study of Davendralingam et al. (2021), a higher frequency of ligamentum arteriosum calcification was observed in children younger than 8

years of age compared to those older than 12 years of age. In the study of Hong et al. (2012), ligamentum arteriosum calcification was most frequently observed between 6 and 10 years of age (48.7%), and no significant difference was found in the prevalence of ligamentum arteriosum calcification among pediatric age groups. In the study of Beluffi et al. (1998), an increase in the frequency of ligamentum arteriosum calcification was found in girls aged 4-6 years. In the studies of Proisy et al. (2015) and Bisceglia and Donaldson (1991), age classifications did not differ significantly in terms of the presence of calcification. In the study of Davendralingam et al. (2021), ligamentum arteriosum calcification was not observed in any patient over 12 years of age. However, in this study, patients over the age of 12 constituted a very small portion of the patient population (10/220). The majority of the patient population consisted of patients in the 0-to-1-year age group (118/220). It is supported that the frequency of ligamentum arteriosum calcification is lower in studies conducted in adult patients (Keys and Shapiro, 1943; Wimpfheimer et al., 1996) than in studies conducted in the pediatric population (Bisceglia and Donaldson, 1991; Beluffi et al., 1998; Hong et al., 2012; Proisy et al., 2015). Hong et al. (2012) reported in their study that the frequency of ligamentum arteriosum calcification decreased with increasing age (in people over 30 years old). In our study, the age range in which ligamentum arteriosum calcification was seen at the lowest rate (10%) was the 0-to-1-year age range with the lowest rate of the population (n:10). The calcification rate was highest (15/36; 41.7%) between the ages of 8 and 9; however, in our study, age classifications did not differ significantly in terms of the presence of calcification. The patient population of our study was more homogeneous than the patient population of Davendralingam et al. (2021). It is thought that this homogeneity increases the sensitivity of the incidence of calcification according to age in our study. As a result of the COVID-19 pandemic, more pediatric patients underwent non-contrast thoracic CT scans, and more people participated in our study. To the best of our knowledge, our study had the highest population evaluated for non-contrast thoracic CT scans in the literature (Table 3). Due to this situation, our study may have a higher sensitivity than other studies.

There was no discernible difference in the gender distribution in our study when compared to other studies. However, only in the study of Beluffi et al. (1998), there was a slight female gender predominance.

There were some limitations in our study worth mentioning. One of them is the fact that the rate of patients aged between 0 and 1 years is lower than

Table 3. Previous studies investigating ligamentum arteriosum calcification in the pediatric population.

Study	Study Group	Population	Calcification Frequency	Gender Distribution	Median Age
Bisceglia and Donaldson (1991)	Living infants and children	Unenhanced CT: 53	Unenhanced CT:7 (13.2%)	No significant difference	Unspecified
Beluffi et al. (1998)	Living infants and children	Radiography: 38.476	Radiography:32 (0.1%)	Slight female predominance	Unspecified
Hong et al. (2012)	Living infants and children	Unenhanced CT: 164 Enhanced CT: 336 Radiography: 476	Unenhanced CT: 62 (37.8%) Enhanced CT: 55 (16.3%) Radiography: 17 (3.6%)	No significant difference	6.8 years
Proisy et al. (2015)	Post mortem infants and children	Unenhanced CT: 69	Unenhanced CT: 42 (60.9%)	No significant difference	9.7 month
Davendralingam et al. (2021)	Post mortem infants and children	Unenhanced CT: 220 Radiography: 182	Unenhanced CT: 67 (30.5%) Radiography: 3 (1.6%)	No significant difference	2.3 years

CT: Computed tomography, %: Percentage

the other age groups. The possible reason is that it is difficult to obtain optimal quality of radiological examinations, especially CT, in 0-to-1-year age group due to the lack of patient orientation, and to protect these patients in infancy from radiation exposure. In our study, 1.5 mm sections were routinely used in CT scans in children, and the sensitivity of the detection of subtle-punctate calcifications decreased due to the current section thickness. Examination of thinner sections may increase the sensitivity of the detection of subtle-punctate calcifications. Due to the prevalence of pediatric patients and the fact that patient orientation declines with age, optimization of the examination also decreases. One of the limitations of our study is that the study was carried out on live patient groups, which may cause respiratory and movement artifacts.

In conclusion, ligamentum arteriosum calcification is a common finding in all age groups in the pediatric population. Non-contrast thorax CT can detect it better than chest radiography. It is most commonly observed as coarse-linear type calcification, and if calcification is present, it can be easily detected on CT. Radiologists should be able to differentiate ligamentum arteriosum calcification found in the pediatric population from other pathological and anatomical conditions when reporting pediatric CT studies in order to avoid needless additional investigations.

STATEMENTS AND DECLARATIONS

This study has been approved by the institutional ethics committee (Ethics Commitee of Clinical Researches of Erzincan Binali Yıldırım University, Protocol number: E-21142744-804.99-96230, Date: 26.07.2021). The authors of this study received no financial support for this research and publication of the article.

The datasets generated and/or analyzed during the current study are not publicly available due to the risk of breach of patient data privacy but are available from the corresponding author (without patients private data) upon reasonable request.

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