The Value of Carina Angle Measurement for the Diagnosis of Patent Ductus Arteriosus

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ABSTRACT

Objectives: We aimed to assess whether the widened carina angle displayed on X-ray supports the presumptive presence of patent ductus arteriosus.

Methods: The study group was arranged by 60 infants under 37 weeks diagnosed with hemodynamically significant patent ductus arteriosus. The control group was constituted by 60 infants with no clinical or echocardiographic evidence of patent ductus arteriosus. In both groups, the location of the left main bronchus was assessed by measuring the angle between two main bronchi at the level of carina.

Results: In the comparison between two groups, a significant widening of carina angle was found in patent ductus arteriosus group and while the interquartile range was found as 69-108 °, the median was found as 89° and the mean was 87.26 ° (± 7.01 °) in study group, these values were found as 57-89°, 66.5° and 67.4° (± 7.33°) respectively, in the control group ($p < 0.001$). We found a significant and positive correlation between the increased carina angle values and patent ductus arteriosus occurrence ($p< 0.01$). When the patent ductus arteriosus was occluded the interquartile range was found as 63- 88 °, the median was 74.5° and the mean was 74.7.26 ° (± 6.4 °) ($p< 0.001$).

Conclusions: We demonstrated that the probability of the appearance of a widened carina angle on X rays was increased by the presence of patent ductus arteriosus.

Keywords: Carina angle, chest X-ray, patent ductus arteriosus, preterm infants

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INTRODUCTİON

A patent ductus arteriosus in the first 3 days of life is a physiologic shunt in healthy term and preterm newborn infants (1). In contrast, a persistently patent ductus arteriosus in preterm infants can have clinical consequences depending on the degree of left-to-right shunting. The increase in pulmonary blood flow in the setting of prematurity can lead to pulmonary edema, loss of lung compliance, and deterioration of respiratory status, which ultimately leads to chronic lung disease. Echocardiography, considered as being the gold standard for diagnosing patent ductus arteriosus (1,2) . It cannot, however, fully replace bedside diagnosis, especially in circumstances where echocardiography is not readily accessible (3). On chest X-ray findings caused by the left atrium enlargement associated with patent ductus arteriosus, such as posterior displacement of the left main bronchus on lateral view, can be detected in preterm infants with patent ductus arteriosus (4). The aim o f this study is to evaluate whether a broaned carina angle supports a posible existence of patent ductus arteriosus seen in a chest X-ray in the spot where left main bronchus is revealed, or not, if so, to ascertain the sensitivity, specificity and usefulness of the carina angle measurement as a tool for assisting in the diagnosis of patent ductus arteriosus in preterm infants.

SUBJECTS AND METHODS

A total of 2548 infants who were hospitalized between January 2009 and January 2013, observed and treated in the Neonatal Intensive Care Unit of the Medical School of Yuzuncu Yıl University, of which 508 were born before 37 weeks of gestation and were eligible to enter our study. We retrospectively reviewed all medical charts, echocardiographic tracings and chest X-rays. The instutional ethical board approved the study. Excluded were 12 infants who died within the first 48 h of life, 18 infants who had congenital heart disease, and 126

infants who had no respiratory symptoms and did not undergo chest X-ray. Also excluded were 160 infants who had minor respiratory symptoms and who underwent only one chest X-ray during the first 2 days of life as well as 132 infants whose low-quality chest X-ray or significant rotation of the chest did not allow for adequate measurement of the carina angle. In conclusion, the patent ductus arteriosus group was constituted by 60 infants under 37 weeks with a diagnosis of patent ductus arteriosus supported by compatible chest X-ray and positive echocardiographic findings and clinical manifestations of patent ductus arteriosus. Infants who were included in the study had at least one of the following findings. These findings and symptoms were new onset systolic murmur, a wide pulse pressure (systolic pressure minus diastolic pressure > 40 mm Hg), increased pericardial impulse, congestive heart failure with no evidence of another cause or respiratory support requiring to stop feeding. All patients underwent echocardiographic examination in order to justify the diagnosis and the ductus was viewed anatomically by color Doppler flow imaging and left atrial-to -aortic root ratio was measured. The echocardiographic examinations were performed using a commercially available echocardiography device (Vivid 3 General Electric, USA ®) equipped with a 7S probe.

In infants constituting the study group, the presence of patent ductus arteriosus was justified by echocardiographic and chest X-ray examinations performed on the same day. The control group was constituted by 60 infants under 37 weeks matched born neonates between January 2009 and January 2013 with an available chest X-ray taken on the same day of a physical examination that raised no clinical or echocardiographic evidence of patent ductus arteriosus or congenital heart disease. The carina angle was measured in both study and control groups on the day of first admission to neonatal intensive care unit in study group and first postnatal day in control group, however in the presence of ductus arteriosus, the carina angle was measured after the occlusion. In patent ductus arteriosus group, the carina angle

was remeasured between the 12th and 37th days after the treatment and the occlusion of patent ductus arteriosus was confirmed by echocardiographic examinations. The patients with hemodynamically significant patent ductus arteriosus (murmur, hypotension, respiratory disorders, the presence of hyperactive precardium, a left atrial to aortic root ratio greater than1.3 or the narrowest ductal diameter greater than 1.5mm on echocardiographic examination) were given oral or enteral ibuprofen treatment. In case of the failed medical closure and a hemodynamically significant ductus, the ductus was occluded surgically.

Measurement of the location of the bronchus

In order to assess the location of the left main bronchus, the angle between the lower borders of two main bronchi was measured at the level of carina (Figure 1). A 5760/57 multıx pro, 150 kV, 500 mA, general radiological imaging software with a serial number o f T04914 (Philips EasyVision, version r10.2 L5, 2006; Philips Medical Systems; Holland), was used to measure the carina angle. All X-ray examinations in study group and control group were performed in anteroposterior direction. Three independent measurements were performed by three different pediatricians who were unaware of the clinical course, the outcome and the results of the echocardiography. The average of the three carina angle measurements was taken for analysis.

Statistical analysis

A SPSS for Windows 15.0 Sofware package was used to analyze data. Descriptive statistics were expressed as mean ± standard deviation or median. (minimum-maximum). Nominal variables were expressed as the number of the cases and (%). The treatment groups were compared using Student's t test. We performed a ROC analysis in order to determine the angle value that can be used as a clinical cut off point to make the diagnosis of patent ductus arteriosus in preterm infants.

RESULTS

Out of the 60 patients with patent ductus arteriosus, 36 were males (60%) and 24 were females (40%). 30 (%50) of the cases in the control group were males and 30 (%50) were females. In the comparison of the study group with the control group, no significant difference was found between two groups in terms of age, birth weight, use of inotropic support, respiratory rate and oxygen saturation. The patent ductus arteriosus group had a lower diastolic systemic blood pressure on the day of diagnosis (27.2± 12.2 mm Hg for patent ductus arteriosus, 34.4± 12.2 mm Hg for non- patent ductus arteriosus, $p < 0.005$). A systolic murmur was present in 80% (n = 48) of the patent ductus arteriosus infants compared to 6.6% (n = 4) of the no- patent ductus arteriosus infants ($p<0.001$). A wide pulse pressure and bounding pulses were found in 80% (n = 48) of the patent ductus arteriosus infants compared to no bounding pulses or wide pulse pressure in the no- patent ductus arteriosus group ($p < 0.001$). The clinical characteristics of the patent ductus arteriosus and no- patent ductus arteriosus infants are shown in table 1.

The carina angle was measured as described in the methods section. No significant difference was found between the three independent measurements in terms of carina angle measurements. In the comparison of two groups, a significant widening of carina angle was found in patent ductus arteriosus group. While the interquartile range was found as 69- 108 °, median was found as 89° and the mean was 87.26 ° (± 7.01 °) in this group, these values were found as 57-89°, 66.5° and 67.4° (± 7.33°) respectively, in the control group ($p < 0.001$). We performed a ROC analysis in order to determine the angle value that can be used as a clinical cut off point to make the diagnosis of patent ductus arteriosus in preterm infants and among them, we preferred the best combination of the specificity, sensitivity and positive or negative predictive values. A cut-off point of 73.5 ° signifies the highest sensitivity (97%) and specificity (55%). The positive predictive value was determined as 65%, negative predictive

value was 93% and the test reliability was determined as 71%. We found a significant and positive correlation between the increased carina angle values and patent ductus arteriosus occurrence ($p< 0.01$) (Figure 2). In addition we also examined the carina angle alterations occurred after the resolution of the patent ductus arteriosus. In the patent ductus arteriosus group, carina angle was remeasured between the 12th and 37th days and the closure of patent ductus arteriosus was confirmed by echocardiography. While the carina angle was measured as 87.2 ° (±7 °)

when the ductus arteriosus was patent, the carina angle was observed to regress to 74.7 ° (±6.4 °) after the closure ($p< 0.001$).

DİSCUSSİON

While the ductus arteriosus plays an important role in fetal circulation, its closure generally occurs within the first 3 days after birth, however the closure may be delayed or may not occur in preterm infants. In premature patients, early diagnosis and appropriate treatment of patent ductus arteriosus may reduce mortality and morbidity (1,5). The morbidities are due to pulmonary overcirculation and end-organ hypoperfusion. Associated short-term morbidities include metabolic acidosis, intracranial hemorrhage, necrotizing enterocolitis and renal insufficiency, all of which could cause permanent damage i f not given immediate attention. The long-term morbidities mainly include bronchopulmonary dysplasia and periventricular leukomalacia (3,6,7). Bedside echocardiography is the golden standard for the diagnosis of patent ductus arteriosus (3). Unfortunately, the provision of appropriate equipment and experienced professionals still constitutes a problem. A more specific finding on chest x-ray is the obliquity that

becomes prominent towards the cardiac apex formed by the left ventricular and atrial enlargement. In a study conducted by Hirschklau et al. (8) 30 babies with patent ductus arteriosus underwent chocardiography for the assessment of ductal size and all but seven revealed an increased left atrium size. Posterior location of left main bronchus in lateral view as well as an enlarged image of left atrium on x rays related to the patent ductus arteriosus are the findings that may be observed in infants with patent ductus arteriosus. In neonatal intensive care services, chest x-ray examinations are routinely performed during the first week of life in preterm infants with respiratory symptoms and in all infants on mechanical ventilation. The measurement of carina angle is easy, reproductive and gives relatively accurate results. Therefore a carina angle value measured on the chest X-ray is an objective clinical diagnostic and easily accessible tool for the diagnosis of patent ductus arteriosus in these infants. A left to right blood shunt without any clinical finding (systolic murmur, bounding pulse or increased pulse pressure) is unlikely to be of clinical significance or not as intensive as to cause the widening of carina angle. Consequently, in spite of the limitations, clinical observations combined with a widened carina angle may provide us valuable information in making the diagnosis of patent ductus arteriosus. Strauss et al. (9) found a significant widening of carina angle was

found in the patent ductus arteriosus group while the interquartile range in this group was found as 97- 107°, the median value was found as 101° and the mean was 99.9 ° (± 12.1 °) in patent ductus arteriosus group, these values were found as 62.3-81.3 °, 69.5 ° and 72.9 ° (± 15.7 °) respectively in the group without patent ductus arteriosus and the difference was found as statistically significant ($p < 0.001$). Similarly in our study, in comparison between two groups, a significant widening of carina angle was found in patent ductus arteriosus group. While the interquartile range was found as 69- 108 °, median was found as 89° and the mean was 87.26 ° (± 7.01 °) in patent ductus arteriosus group, these values were found as 57-

89°, 66.5° and 67.4° (± 7.33°) respectively, in the control group ($p < 0.001$). In addition we also examined the carina angle alterations occurred after the resolution o f the patent ductus arteriosus. In the patent ductus arteriosus group, carina angle was remeasured between the 12th and 37th days and the closure of patent ductus arteriosus was confirmed by echocardiography. While the carina angle was measured as 87.2 ° (±7 °) when the ductus arteriosus was patent, the carina angle was observed to regress to 74.7 ° (±6.4 °) ($p < 0.001$). The closure of the ductus arteriosus and by using the carina angle measurements indicating the narrowing of the carina angle after the justification o f closure by echocardigraphic examination, the patent ductus arteriosus group

also acted as a self control group. Strauss et al. (9) found after the closure following the treatment, the carina angles were remeasured and similarly to our study, a significant narrowing of the angle was detected [99.9° (± 12.1°) versus (62.3° (± 10.8°) ($p < 0.001$)] [9].

Our results demonstrated that the prominent posterior displacement of left main bronchus observed as the widening of the carina angle on chest X-rays indicated the presence of patent ductus arteriosus in preterm infants. We demonstrated that the probability of the appearance of a widened carina angle on X rays was increased by the presence of patent ductus arteriosus. The mean values for tracheal angle was accepted as 60.8 ° and the angle was not related to age and sex and it was pointed out that carina angle might also increase in conditions such as subcarinal mass, lobar collapse, left atrial enlargement, cardiomegaly or pericardial effusion (10). The bifurcation angle was formulized as y= (71. 915 -0.71 x age) in children (11). The most important limitation of our study is that complex forms of congenital heart disease that may mascarade as a significant patent ductus arteriosus and produce a dilated left atrium with changes in the carinal angle. Another limitation of our study was about the measurement of carina angel because of that we used a computer-based software

which may be unavaliable in many countries. It can be measured manually hovewer the measurement on chest X-ray in small babies may be inaccurate and inconclusive.

In another study conducted by Karabulut et al. (12) in an adult age group, subcarinal angle was found to be related to left atrial enlargement, female sex and obesity. The subcarinal angle was found to be 69 ° ±14 (34 ° -105) in patients with normal left atrial size and 79 ° ± 15 (40 ° -107 °) in patients with an increased left atrial size. In adults, the increased tracheal carina angle was reported to be related to left atrial enlargement and a left atrial enlargement of 5.0 cm was associated with a presumable carina angle of 100 ° and over (13). The early detection and treatment of patent ductus arteriosus in preterm infants is important in terms of the complications that may develop. Although the echocardiographic examination is the golden key for the diagnosis, in case of unavailability of an echocardiographic examination, left bronchus displacement characterized by the widening of the angle between two main bronchi that may be shown on plain chest X-ray, may provide accurate information for the early diagnosis of patent ductus arteriosus. In our study, a cut-off point of 73.5 ° signified a sensitivity of 97% and a specificity of 55% .

CONCLUSİON

We demonstrated that the probability of the appearance of a widened carina angle on X-ray was increased by the presence of patent ductus arteriosus. Similarly, a carina angle narrower than 73.5 ° and a negative predictive value of 93% eliminate the diagnosis of patent ductus arteriosus.

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Conflicts of Interest

None.

Ethical Standards

The research does not involve human and/or animal experimentation.

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Table 1. Clinical characteristics of suitable subjects with and without patent ductus arteriosus.

	PDA (n:60)	Control (n:60)	p value
Gestational age, weeks	**30.1±3,08**	**30.5±3.2**	**0.42**
Birth weight, g	**1040.2±474.8**	**1080.2±350**	**0.45**
Male (n, %)	**36(60%)**	**30(%50)**	**0.48**
Inotropic support(n %)	**21(35%)**	**18(30%)**	**0.65**
Respiratory distress syndrome(n, %)	**33(55%)**	**27(45%)**	**0.2**
Diastolic arterial pressure, mm Hg	**27.2±12.2**	**34.4±12.2**	**<0.005**
Wide pulse pressure and bounding pulses, %	**80**	**3.3**	**<0.001**
Systolic murmur (n %)	**48(80%)**	**3(5%)**	**<0.001**
Oxygen saturation, %	**90.3±10.6**	**91.5±4.1**	**0.3**

P<0.05 indicates statistical significance, n:number, PDA. Patent ductus arteriosus

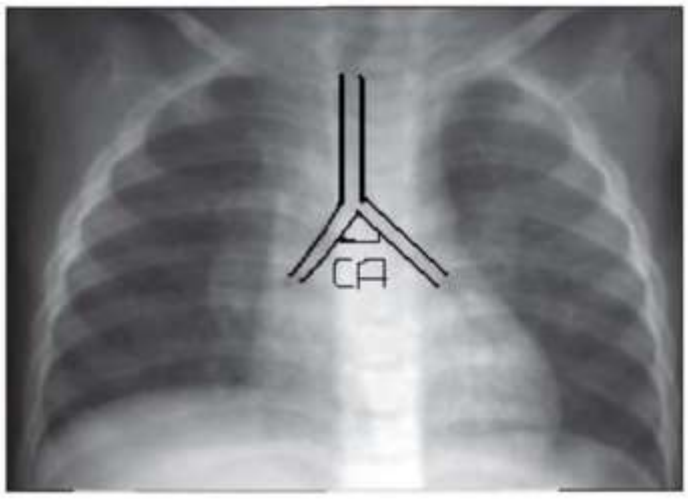

Figure 1: The technique used to measure the carina angle (CA) between the two main bronchi.

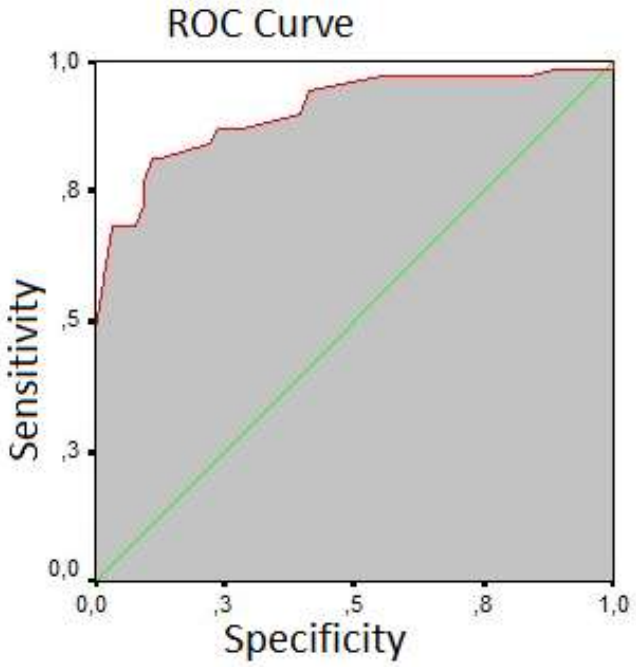

Figure 2: ROC curve showing the correlation between patent ductus arteriosus and the carina angle