

# Predictive Value of Doppler Ultrasound in Childhood Pneumonia

E YEKELER<sup>1</sup>, A UCAR<sup>1</sup>, R YILMAZ<sup>1</sup>, E YILMAZ<sup>1</sup>, I CHEIKAHMAD<sup>1</sup>, R SHARIFOV<sup>1</sup> AND A SOMER<sup>2</sup>

<sup>1</sup>Department of Radiology, and <sup>2</sup>Department of Paediatrics, Faculty of Medicine, Istanbul University, Istanbul, Turkey

This study aimed to determine the predictive value of intercostal and pulmonary artery Doppler flow patterns in the outcome of childhood pneumonia. Pneumonia was classified according to type of pleural effusion and the ultrasound features of consolidations. Doppler flow patterns of intercostal and pulmonary arteries were analysed and correlated with pneumonia type and hospital stay. Of 83 pneumonia cases, 55 were uncomplicated

and 28 were complicated. Pleural effusion was present in 54 cases, with 29 non-septated and 25 septated cases. Patients with uncomplicated pneumonia did not have abnormal Doppler flow patterns, compared with 64% (18 of 28) of patients with complicated pneumonia. Doppler ultrasound patterns in childhood pneumonia were correlated with pneumonia type and may be predictive of pneumonia outcome.

**KEY WORDS:** PNEUMONIA; DOPPLER ULTRASOUND; INTERCOSTAL ARTERY; PULMONARY ARTERY; CHILDREN

## Introduction

Ultrasound of the chest has been widely used in children in the past three decades and is assisted by the wide acoustic window of the paediatric thymus.<sup>1-6</sup> It is most commonly used to evaluate pleural effusion and pneumonia. In addition to grey-scale ultrasound, the examination of pulmonary vessels with Doppler ultrasound can be useful in the differentiation of pulmonary opacities such as pneumonia, atelectasis, thymic variations, sequestration and tumours.<sup>7-12</sup>

Doppler flow patterns in pulmonary and bronchial arteries have been used to characterize pulmonary consolidations;<sup>13</sup> however, there have been no similar studies of intercostal arteries. Several studies have used grey-scale ultrasound to predict the

clinical outcome of pneumonia cases,<sup>14,15</sup> but these have not evaluated intercostal or pulmonary arteries.

The present study examined changes in the Doppler flow patterns of both intercostal and pulmonary arteries, and compared them with pneumonia type and duration of hospital stay in order to determine whether this method has a predictive value for pneumonia outcome.

## Patients and methods

### STUDY POPULATION AND EVALUATIONS

Children of ages 1 month – 15 years who had been newly diagnosed with pneumonia based on clinical, laboratory and chest X-ray findings were recruited consecutively from

the Department of Paediatrics, Faculty of Medicine, Istanbul University, Istanbul, Turkey, between September 2006 and November 2009. They were evaluated via Doppler ultrasound on the first day of hospital admission to characterize the pneumonia and for analysis of intercostal and pulmonary artery flow patterns. Healthy control children were also recruited from among patients referred to the Department of Radiology, Faculty of Medicine, Istanbul University for reasons unrelated to the chest and underwent analysis of their intercostal artery Doppler flow pattern. The ages of the control subjects were matched to those of the patient group. Exclusion criteria were previous surgery for thoracic pathologies in both groups and the presence of chest complaints for the control subjects.

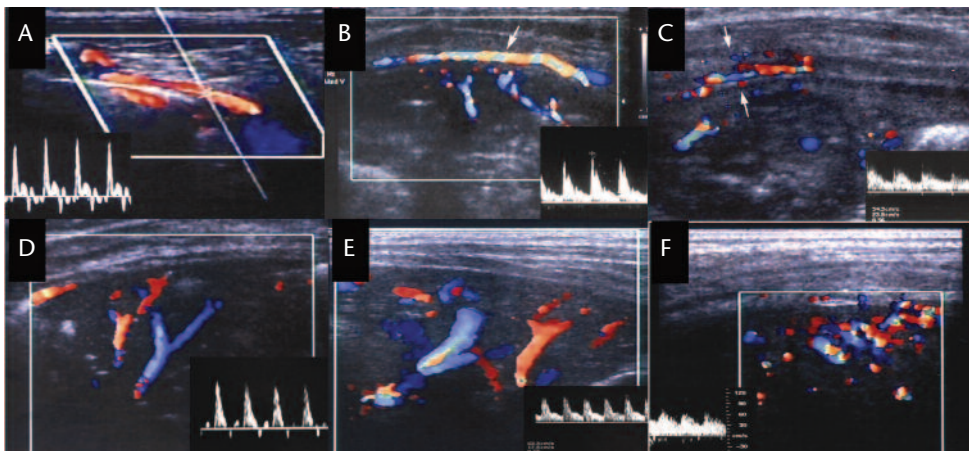
The study was approved by the Ethical Committee of the Faculty of Medicine, Istanbul University and written informed consent was obtained from the patients' parents.

## DOPPLER ULTRASOUND

Thorax Doppler ultrasound examinations were performed with a duplex Doppler system (HDI 5000; Philips Medical Systems, Best, The Netherlands) using 3 MHz convex, 5 – 9 MHz microconvex and 10 MHz linear transducers according to the depth of the evaluated area. Pleural effusion was classified, based on ultrasound appearance, as non-septated, septated or multiloculated. Complicated pneumonia was diagnosed as the presence of septated or multiloculated effusion and/or abscess formation or parenchymal destruction within the pneumonic consolidation. Flow patterns of intercostal and pulmonary arteries were classified as normal (regular-triphasic) or abnormal (regular-monophasic or irregular-monophasic) (Fig.1).

## STATISTICAL ANALYSES

All statistical analyses were performed with SPSS® statistical software, version 12 (SPSS



**FIGURE 1:** Typical colour and spectral flow patterns of: (A – C) intercostal; and (D – F) pulmonary arteries, that were seen in the children studied (A and D, regular-triphasic; B and E, regular-monophasic; C and F, irregular-monophasic). Regular-triphasic pattern of intercostal arteries (A) was seen in both control and patients groups. The other patterns (B – F) were seen only in the patient group

Inc, Chicago, IL, USA) for Windows®. The Mann–Whitney *U*-test was used to compare parameters with two variables. Categorical variables were compared using the  $\chi^2$ -test. Correlations were made using bivariate correlation analysis. For data sets with more than two variables, a non-parametric analysis of variance (Kruskal–Wallis) was performed and Bonferroni adjustment was applied for *P*-values in those cases. A *P*-value < 0.05 was considered to be statistically significant.

## Results

The study recruited 83 children with pneumonia (46 males/37 females; aged 1 month – 15 years; mean age 5 years) and 20 healthy control children (11 males/nine females; aged 1 month – 15 years; mean age 5 years). Of the 83 pneumonia patients, 54 had pleural effusion (29 non-septated, 18 septated and seven multiloculated). In three patients without pleural effusion, pulmonary abscess (*n* = 2) and parenchymal destruction (*n* = 1) were seen. Final diagnosis was 55 children with uncomplicated pneumonia and 28 with complicated pneumonia. Seventy of the children with pneumonia were hospitalized for treatment because of complicated pneumonia (*n* = 28), uncomplicated pneumonia with non-septated pleural effusion (*n* = 29) and severe clinical conditions (*n* = 13). The remaining, uncomplicated pneumonia, patients were treated as out-patients (*n* = 13).

Abnormal flow patterns (regular-monophasic and irregular-monophasic) in the intercostal and pulmonary arteries were not seen in any of the 55 uncomplicated pneumonia patients, but were observed in 64% (18 of 28 patients) of complicated pneumonia cases (*P* < 0.001). The Doppler flow pattern in the intercostal arteries of the healthy controls was normal (regular-

**TABLE 1:** Length of hospital stay and intercostal and pulmonary artery Doppler flow patterns in 70 hospitalized childhood pneumonia patients

	Intercostal artery Doppler flow pattern			Pulmonary artery Doppler flow pattern		
	Regular-triphasic	Regular-monophasic	Irregular-monophasic	Regular-triphasic	Regular-monophasic	Irregular-monophasic
No. of patients	51	14	5	58	11	1
Length of hospital stay, days, mean $\pm$ SD	14.22 $\pm$ 9.31	21.71 $\pm$ 7.14	4.06 $\pm$ 18.12	14.57 $\pm$ 8.99	29.18 $\pm$ 9.06	66
			<i>P</i> < 0.001			<i>P</i> < 0.001

<sup>a</sup>Non-parametric analysis of variance (Kruskal–Wallis) with Bonferroni adjustment for *P*-values; differences were highly significant between the three subgroups.

triphasic) in all cases, as was also seen in those patients with non-septated pleural effusion. In patients with pulmonary abscess ( $n = 2$ ) or parenchymal destruction ( $n = 1$ ), pulmonary artery flow patterns were regular-monophasic and irregular-monophasic, respectively.

In all hospitalized patients ( $n = 70$ ), mean duration of hospitalization varied significantly, according to Doppler flow patterns of the intercostal and pulmonary arteries, between the three subgroups; the more complex the Doppler flow pattern, the longer the hospital stay and the more complicated the pneumonia ( $P < 0.001$ ,  $r = 0.77$  for intercostal arteries and  $P < 0.001$ ,  $r = 0.56$  for pulmonary arteries) (Table 1).

## Discussion

Doppler ultrasound provides more diagnostic information than grey-scale imaging alone<sup>7-13</sup> and is able to detect small amounts of pleural effusion.<sup>16</sup> Pneumonias may be diagnosed via visualization of normal pulmonary artery branches within a consolidated area,<sup>7-9,13,17</sup> and a lack of vascularity within the wedge-shaped pleural-based consolidation may suggest pulmonary infarction.<sup>18</sup>

As well as providing valuable diagnostic information, the predictive value of ultrasound has been investigated in several studies according to the type of pleural effusion. For example, Chen *et al.*<sup>14</sup> found that patients with septated pleural effusion

had a significantly longer hospital stay than those with non-septated pleural effusion, and Ramnath *et al.*<sup>15</sup> demonstrated significantly shorter hospitalization for patients who underwent early surgery for complicated pleural effusion compared with the non-operative group.

There have been no previous studies on the predictive value of intercostal and pulmonary artery Doppler flow patterns. The present study demonstrated that intercostal arteries have a regular-triphasic flow pattern in both healthy control subjects and in patients with uncomplicated pneumonia. The pulmonary artery flow pattern remains regular-triphasic within a pneumonic consolidation, until complications such as parenchymal destruction and abscess formation occur.<sup>13</sup> The presence of a normal (regular-triphasic) intercostal and pulmonary artery flow pattern may be predictive of more rapid recovery, as shown by the shorter hospital stay for these patients.

In conclusion, Doppler ultrasound should be used routinely as a complementary modality in the evaluation of pulmonary consolidations. Intercostal and pulmonary artery flow characteristics may be predictive of the course of pneumonic consolidations in children.

## Conflicts of interest

The authors had no conflicts of interest to declare in relation to this article.

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Author's address for correspondence

Associate Professor Dr Ensar Yekeler

Istanbul Tıp Fakültesi Radyoloji, Capa 34094, Istanbul, Turkey.

E-mail: yekelerensar@yahoo.com