Objective. We assessed the accuracy of thin-section CT and chest radiography to diagnose pediatric interstitial lung disease.

Materials and Methods. We identified 20 infants, boys, and girls (age range, 1 month to 14 years) with histopathologic confirmation of interstitial lung disease. Six boys and girls without interstitial lung disease were also included. Two observers independently assessed chest radiograph and CT images. The observers stated the most likely diagnosis and a differential diagnosis. We evaluated individual CT features and their distribution.

Results. Observers' diagnoses on CT images were correct (first choice or differential) in 66% of observations versus 45% on chest radiographs ($p < 0.025$). Correct diagnoses were made on first choice in 61% of CT observations versus 34% on chest radiographs ($p < 0.005$). Observers were confident (versus uncertain) in 42% of the CT observations versus 18% on chest radiographs; of the confident diagnoses made on CT, 91% were correct. CT interpretations were most accurate in the diagnosis of pulmonary alveolar proteinosis, congenital lymphangiectasia, and idiopathic pulmonary hemosiderosis. All healthy patients examined with CT were correctly identified as such. We noted a distinctive CT pattern in three patients with nonspecific interstitial pneumonitis and one patient with desquamative interstitial pneumonitis; the CT pattern consisted of upper zone predominant honeycombing on a background of ground-glass attenuation.

Conclusion. A higher proportion of pediatric interstitial lung diseases can be diagnosed on thin-section CT than on chest radiographs. In our study, confident and correct diagnoses were made more frequently with CT than with chest radiographs.
CT. Six patients were excluded on further review of the biopsy results: biopsy results were nondiagnostic in two patients, diagnosed as tuberculosis in one, diagnosed as bronchopneumonia in one, and diagnosed as acute bronchiolitis but no interstitial lung disease in two. One patient fulfilled our entry criteria but a concurrent chest radiograph was unavailable. The remaining patients had chest radiography within 3 months of CT (range, 0–72 days; mean, 13 days). The final study group comprised 20 patients: 19 patients with open lung biopsy diagnosis and one in whom the diagnosis was made at autopsy.

The female-to-male ratio was 1.86:1. We also included six patients with no clinical or imaging evidence of interstitial lung disease who underwent a clinically indicated thin-section CT examination and remained well 5 years later. This group consisted of four boys and two girls (age range, 3–11 years; mean age, 8 years). Therefore the total study group comprised 26 patients.

A pulmonary histopathologist reviewed histopathologic specimens that consisted of six cases of nonspecific interstitial pneumonitis; two of desquamative interstitial pneumonitis (one with Gaucher’s disease); three of follicular bronchiolitis (one with coexisting cytomegalovirus infection); three of congenital lymphangiectasia; two of lymphocytic interstitial pneumonitis; two of alveolar proteinosis; one of pulmonary alveolar cryptococcosis; one of idiopathic pulmonary hemosiderosis.

Chest radiographs were obtained using an AMBER scanner (Odelft, Delft, Holland) (n = 24) or using a photostimulable phosphor plate computed radiography system (Siemens, Erlangen, Germany) (n = 2). CT was performed using an electron beam scanner (Imatron, San Francisco, CA). CT scans were obtained using the following parameters: 130 kVp, 630 mA, and 3-mm (n = 20) or 1.5-mm (n = 6) section thickness. Three-millimeter collimation was used in young children to allow a reduced scan acquisition time of 100 msec resulting in decreased motion artifacts. Sections were obtained at 6-mm intervals in children under the age of 3 years and 10-mm intervals for all others. A high-spatial-resolution reconstruction algorithm was used, and scans were imaged on windows appropriate for viewing the lung parenchyma (window width, 1500 H; window level, –500 H). In younger children who required sedation, images were obtained with the patient supine during quiet respiration; older children were able to comply with breathing instructions. When sedation was necessary, we used choral hydrate at a rate of 50 mg/kg or triamazine tannate at a rate of 2 mg/kg.

Chest radiographs and CT scans were evaluated independently on separate occasions by two chest radiologists. The observers were unaware of pathologic or clinical data except for the patient’s age and sex. The observers were asked to give the most likely diagnosis and up to two differential diagnoses for the chest radiographs and the CT scans. An indication of confidence (confident versus uncertain) was also recorded. The observers recorded specific CT findings [4] including ground-glass opacification, nodules (size and character), thickened interlobular septa, honeycomb pattern, parenchymal distortion, traction bronchiectasis, consolidation, and ancillary features such as pleural effusions. The distribution of these findings was also evaluated: upper zone predominance, middle zone predominance, lower zone predominance, peripheral predominance, and random distribution.

For the purposes of analysis, the results of the two observers were added so that for 26 patients there were 52 observations. McNemar test was used to compare CT and chest radiography observations (p < 0.05 regarded as statistically significant).

### Results

A correct first-choice diagnosis was made in 61% of CT scan observations versus 34% of chest radiograph observations (p < 0.005), irrespective of confidence level. The diagnosis was correct (either as the most likely diagnosis or as the differential) in 66% of CT observations versus 45% of chest radiograph observations (p < 0.025). The observers assigned confident to their first-choice diagnosis in 42% of CT scans and in 18% of chest radiographs. Confident diagnoses were more likely to be correct with CT (91%) than with chest radiographs (70%). The observers agreed on the correct first-choice diagnosis in 65% of CT scans and 58% of chest radiographs.

Table 2 summarizes the percentages of correct diagnoses irrespective of confidence. All normal instances of pulmonary alveolar proteinosis and idiopathic pulmonary hemosiderosis were correctly identified on CT, whereas interstitial pneumonias (nonspecific pneumonitis, desquamative interstitial pneumonitis, and lymphoctic interstitial pneumonitis) and follicular bronchiolitis were less accurately diagnosed.

Table 3 summarizes the percentages of diagnoses that were made with a high degree of confidence. The observers were more confident in classifying findings as normal on CT (12/12 patients) than on chest radiographs (7/12 patients). In findings with a confident assignment of normality (on CT and chest radiographs), the observers were 100% correct. Table 2 summarizes the percentages of correct confident diagnoses. The observers were uncertain in diagnosing a case of interstitial lung disease on chest radiographs showing abnormalities except for one patient with pulmonary lymphangiomatosis for whom both observers confidently, and incorrectly, diagnosed congenital lymphangiectasia. The observers were confident in their diagnosis of pulmonary alveolar proteinosis and congenital lymphangiectasia on CT and were correct in all cases.

Table 3 summarizes the CT findings for various pediatric interstitial lung diseases. All CT features displayed a random distribution except for nonspecific interstitial pneumonitis and one case of desquamative interstitial pneumonitis. A

### Table 1: Accuracy of Diagnosis (Regardless of Confidence)

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>No. of Patients</th>
<th>High-Resolution CT</th>
<th>Chest Radiography</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>First-Choice Diagnosis (%)</td>
<td>Differential Diagnosis (%)</td>
</tr>
<tr>
<td>Normal</td>
<td>6</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Idiopathic interstitial pneumonitis (NSIP + DIP)</td>
<td>8</td>
<td>50</td>
<td>13</td>
</tr>
<tr>
<td>Lymphangiectasia</td>
<td>3</td>
<td>83</td>
<td>16</td>
</tr>
<tr>
<td>Follicular bronchiolitis</td>
<td>3</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>Alveolar proteinosis</td>
<td>2</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Lymphocytic interstitial pneumonitis</td>
<td>2</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Idiopathic pulmonary hemosiderosis</td>
<td>1</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Lymphangiomatosis</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note:—NSIP = nonspecific interstitial pneumonitis, DIP = desquamative interstitial pneumonitis.
similar pattern was found in three of six patients with nonspecific interstitial pneumonitis and in one patient with desquamative interstitial pneumonitis: a predominantly upper zone honeycomb pattern with parenchymal distortion superimposed on a background of widespread ground-glass opacification (Figs. 1 and 2). Of the other three patients with nonspecific interstitial pneumonitis, one showed widespread ground-glass opacification, honeycombing with a mid and lower zone predominance, and traction bronchectasis; one showed widespread ground-glass opacification; and one showed widespread ground-glass opacification with peripheral consolidation. The patient with desquamative interstitial pneumonitis and Gaucher’s disease showed widespread ground-glass opacification and patchy consolidation (Fig. 3).

One of three patients with follicular bronchiolitis had nodules and ground-glass attenuation on CT. The CT findings in the other two patients were nonspecific: one patient showed widespread ground-glass opacification with minor consolidation, whereas the third patient showed evidence of airway disease reflected by a mosaic attenuation pattern and plugged bronchi. The two patients with lymphocytic interstitial pneumonitis showed profuse nodules (3 mm in diameter) in one patient (Fig. 4) and a mosaic attenuation pattern and slightly thick-walled bronchi, suggestive of small airways disease, in the other patient. The patient with idiopathic pulmonary hemosiderosis showed ground-glass opacification of variable intensity with superimposed ill-defined randomly distributed nodules (2–3 mm in diameter).

CT and Radiography of Pediatric Interstitial Lung Disease

| TABLE 2 | Accuracy of Confident Diagnoses |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Diagnosis | No. of Patients | High-Resolution CT | No. of Confident Diagnoses<sup>a</sup> | Percentage of Correct Diagnoses | No. of Confident Diagnoses<sup>a</sup> | Percentage of Correct Diagnoses |
| Normal | 6 | 12 | 100 | 7 | 100 |
| Idiopathic interstitial pneumonitis (NSIP + DIP) | 8 | 1 | 100 | 0 | 0 |
| Lymphangiectasia | 3 | 3 | 100 | 0 | 0 |
| Follicular bronchiolitis | 3 | 0 | 0 | 0 | 0 |
| Alveolar proteinosis | 2 | 4 | 100 | 0 | 0 |
| Lymphocytic interstitial pneumonitis | 2 | 0 | 0 | 0 | 0 |
| Idiopathic pulmonary hemosiderosis | 1 | 0 | 0 | 0 | 0 |
| Lymphangiomatosis | 1 | 0 | 0 | 2 | 0 |

Note.—NSIP = nonspecific interstitial pneumonitis, DIP = desquamative interstitial pneumonitis.
<sup>a</sup>Two observations per patient.

| TABLE 3 | Features of High-Resolution CT |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Diagnosis | Ground-Glass Opacification | Honeycomb Pattern or Cysts | Thickened Interlobular Septa | Nodules | Parenchymal Distortion | Consolidation |
| Normal | ++++ | +++ | – | – | +++ | + |
| Idiopathic interstitial pneumonitis (NSIP + DIP) | ++++ | ++ | – | – | ++ | ++ |
| Lymphangiectasia | ++ | – | ++++ | – | – | – |
| Follicular bronchiolitis | ++ | – | – | + | – | + |
| Alveolar proteinosis | ++++ | – | ++++ | – | – | – |
| Lymphocytic interstitial pneumonitis | – | – | – | ++ | – | – |
| Idiopathic pulmonary hemosiderosis | ++++ | – | – | ++++ | – | – |
| Lymphangiomatosis | ++++ | – | ++++ | – | – | – |

Note.—NSIP = nonspecific interstitial pneumonitis, DIP = desquamative interstitial pneumonitis, ++++ = observed in 100% of patients, +++ = observed in 75–99% of patients, ++ = observed in 50–74% of patients, + = observed in 1–49% of patients, – = not present.

Discussion

Researchers have studied the diagnostic accuracy of thin-section CT compared with that of chest radiography in adult diffuse interstitial lung disease [5–7]. CT provides useful prognostic information regarding outcome and treatment in the adult population, particularly in fibrosing
lung disease [8, 9]. However, because of the rarity of these conditions in children, the thin-section CT appearances of pediatric interstitial lung disease have been described only in small series or pictorial reviews [10–13]. Clearly, conclusions drawn from experience with CT in adult patients cannot always be applied to pediatric practice. For example, the prognosis of fibrosing alveolitis, in particular desquamative interstitial pneumonitis, is reported to be worse in children than in adults [14–16].

Our results confirm the superior accuracy of thin-section CT (66% correct diagnoses) compared with that of chest radiography (45% correct diagnoses) in the diagnosis of pediatric interstitial lung disease. CT allows observers to exclude interstitial lung disease with greater accuracy and confidence than chest radiography. Moreover, when our observers were confident in their first-choice diagnosis on thin-section CT, they were correct in 91% of observations. Studies have described instances of relatively specific CT appearances when observers were able to accurately make a diagnosis (e.g., pulmonary alveolar proteinosis and idiopathic pulmonary hemosiderosis) [17, 18]. In these specific conditions, open lung biopsy may be obviated, especially if findings of other examinations (e.g., bronchoalveolar lavage in pulmonary alveolar proteinosis) are consistent with the diagnosis. In our study, pulmonary lymphangiomatosis was misinterpreted by both observers as congenital lymphangiectasia; however, differentiation

**Fig. 1.**—10-month-old female infant with biopsy-proven nonspecific interstitial pneumonitis. 
A, Thin-section CT scan of upper zones shows predominant honeycomb pattern. 
B, Thin-section CT scan of lower zones shows widespread ground-glass opacification.

**Fig. 2.**—13-year-old girl with biopsy-proven desquamative interstitial pneumonitis. 
A, Thin-section CT scan of upper zones shows predominant honeycomb pattern. 
B, Thin-section CT scan of lower zones shows widespread ground-glass opacification. Appearances are similar to those seen in Figure 1.
between the two entities may be impossible using CT findings alone, and histopathologic analysis is not always straightforward [19]. Thin-section CT was less accurate in the diagnosis of the interstitial pneumonias (nonspecific interstitial pneumonitis, desquamative interstitial pneumonitis, and lymphocytic interstitial pneumonitis) and follicular bronchiolitis.

Although histopathologic features of nonspecific interstitial pneumonitis in children have previously been described [20, 21], the CT findings have been described only in adults [22, 23]. To our knowledge, our study is the first description of the thin-section CT appearance of nonspecific interstitial pneumonitis in children.

During the analysis of our CT findings, we noticed a distinctive pattern of involvement with a similar appearance in one patient with desquamative interstitial pneumonitis. We documented a honeycomb pattern involving predominantly the upper zones superimposed on widespread ground-glass opacification. The upper lobe pattern was interpreted as multiple cysts or emphysematous changes by one of the observers. Interestingly, Hewitt et al. [24] observed a plain radiographic pattern with linear and cystic perihilar shadows in a study of 10 children with biopsy-proven “fibrosing alveolitis,” which may be analogous to the CT findings in our study.

One of the cases of idiopathic pulmonary fibrosis illustrated by Seely et al. [12] documented a subpleural pattern of ground-glass opacification with large bullae in the upper lobes.

None of our patients showed the typical histopathologic or thin-section CT findings of usual interstitial pneumonitis. Usual interstitial pneumonitis is described in the pediatric population [25, 16], but such descriptions predate the more recent definition of the histopathologic pattern of nonspecific interstitial pneumonitis. Other studies have described histopathologic features of fibrosing alveolitis but have not attempted to categorize the histopathologic subtype of these cases [26, 14]. Most of these cases would now
probably be reclassified as nonspecific interstitial pneumonitis [27]. Furthermore, Katzenstein [27] reported no proven cases of usual interstitial pneumonitis in a critical review of previously reported cases, calling into question the description of this variant in pediatric practice. A limitation of our study was the use of 3-mm collimated sections in 20 of 26 patients. It is our practice to use 3-mm collimation sections in young children to allow a fast acquisition time of 100 msec to obtain images during gentle respiration. A collimation width of 1.5 mm was reserved for older children who were able to comply with breath-holding instructions. Our results may not be transferable to conventional CT; however, further advances in CT technology are likely to reduce scan acquisition time in the future.

The pretest probability of disease was high, an inherent limitation of similar large retrospective studies in adults [6]. Furthermore, previous studies to assess the diagnostic accuracy of high-resolution CT compared with that of chest radiography in adults have not included healthy volunteers [5, 7]. Although we studied a small number of patients, our study group was larger than any other published series to date. The mean age of patients without interstitial lung disease (youngest patient, 3 years) was greater than the mean age of patients with interstitial disease. There is a greater possibility of false-positive interpretations on thin-section CT for infants—meaning our results may overestimate the specificity of CT. The rarity of these conditions and the lack of previous thin-section CT descriptions of some of the conditions encountered, especially nonspecific interstitial pneumonitis, must be considered when comparing the accuracy of CT and the confidence of observers with those reported in adult diffuse interstitial lung disease. There is also considerable overlap in the histopathologic features of the interstitial pneumonitides, and the classification relied on a subjective assessment by a single histopathologist as to the dominant pattern [21]. The spectrum of disease in our population may not be representative of that in other pediatric practices because some of the common causes of interstitial lung disease, such as chronic aspiration, would not require open lung biopsy and would not have met our inclusion criteria.

In a broader clinical context, Lynch et al. [10] showed that observers could accurately characterize conditions as airway disease, interstitial disease, and processes involving the airspaces using thin-section CT appearances alone. Additionally, observers were able to use thin-section CT to define the extent of disease and to identify abnormalities when chest radiographs appeared to have normal findings. Seeley et al. [11] studied 11 children with scle-roderma and reported CT findings of interstitial lung disease in 91%, including six patients who were thought to have normal chest radiographs. In our study group, none of the patients with interstitial lung disease had normal findings on chest radiographs, possibly because the threshold for requiring children with a normal chest radiograph to open lung biopsy is higher than that in adults.

Future studies are needed to investigate the CT abnormalities of pediatric interstitial lung disease. Because of the rarity of these disorders, a multicenter study would be necessary to accumulate a sufficient number of patients. The increased accuracy of thin-section CT and the increased confidence of observers in making certain diagnoses is encouraging, but increases in diagnostic accuracy using thin-section CT will require further experience in pediatric practice and a more definitive categorization of the histopathology of pediatric interstitial lung disease.

References

12. Seeley JM, Effmann EL, Müller NL. High-resolution CT of pediatric lung disease: imaging findings. AJR 1997;168:1269–1275