ASIAN PACIFIC JOURNAL OF ALLERGY AND IMMUNOLOGY (1999) 17: 69-76

# Use of Standard Radiography to Diagnose Paranasal Sinus Disease of Asthmatic Children in Taiwan: Comparison with Computed Tomography

Li-Chen Chen[1], Jing-Long Huang[1], Chao-Ran Wang[2], Kuo-Wei Yeh[1] and Syh-Jae Lin[1]

**SUMMARY** **Paranasal sinus disease and bronchial asthma are frequently associated. Computed tomography imaging is currently the most reliable method for confirming the diagnosis of sinusitis. Due to the cost and amount of radiation during computed tomography, our aim was to analyze whether standard radiography, under computed tomography-control, had a reasonable degree of confidence in the diagnosis of sinusitis. Fifty-three asthmatic patients (42 males and 11 females) with a mean age of 9 years (range 4-14) were enrolled. We evaluated the maxillary sinuses, ethmoidal sinuses, frontal sinuses, and sphenoidal sinuses using standard radiography (Waters' view, Caldwell view, and lateral view) and compared with computed tomography (coronal views), the latter served as a standard. Computed tomography (CT) showed paranasal sinusitis in 58% (31/53) of the asthmatic children. Compared with the results of computed tomography, standard radiography revealed a sensitivity of 81.1% and a specificity of 72.7% for maxillary sinusitis. The sensitivity and specificity for ethmoidal, frontal, and sphenoidal sinusitis were 51.8%, 84.8%; 47.3%, 87.2%; and 40.8%, 93.3%, respectively. In 21 (40%) of the 53 patients, discrepancies were seen between the interpretations of standard radiography and those of CT scans. In patients with maxillary sinusitis, the correlation between standard radiography and CT was good. However, ethmoidal, frontal, and sphenoidal sinusitis were poorly demonstrated using radiography. Standard radiography can be recommended as a screening method for maxillary sinusitis, but it is not recommended for the diagnosis of other paranasal sinusitis.**

Paranasal sinus diseases are common in asthma patients.[1,2] Haung *et al.*[3] reported that abnormal sinus radiographs were found in 54.7% of asthmatic children in Taiwan. Sinusitis has been described as one of the severe aggravating factors of chronic asthma in both adults and children. Various mechanisms, such as mucosal irritation causing vagally mediated bronchospasm, production of toxins or β-adrenergic blockage by infecting bacteria, and the local production of chemical mediators, such as leukotrienes and eosinophil chemotactic factor, have been implicated as mechanisms through which sinus disease can cause deterioration of health in asthma patients.[4] Several studies of children with sinusitis and hyperreactive airway disease have shown that management of sinusitis results in significant improvement of health in asthma patients.[5,6] It is important to diagnose concomitant sinus diseases in patients with asthma due to the possible therapeutic implication for a decrease in the severity of their asthma, such as treatment with antibiotics, topical steroids, or endoscopic sinus surgery.[7]

A good radiographic view has long been considered the most reliable adjunct in the clinical diagnosis of sinusitis. Computed tomog-

From the [1]Division of Allergy, Asthma and Rheumatology, Department of Pediatrics, [2]Department of Radiology, Chang Gung Children's Hospital, Taoyuan, Taiwan.
Correspondence: Jing-Long Huang

raphy (CT) imaging is currently the most reliable method to confirm the diagnosis of sinusitis.[8,9] While CT imaging provides for more sensitivity and specificity, its use is limited by high cost, limited availability, and the use of high doses of radiation.[10] Thus, standard radiography in different views for the diagnosis of paranasal sinuses is still used by most allergists and otorhinolaryngologists because it is simple, fast, and inexpensive. The present study was undertaken to determine whether standard radiography using prone coronal CT scans as a control is sufficiently sensitive and specific to be used as a screening method for the types of sinus disease common in asthmatic children.

## MATERIALS AND METHODS

### Patient selection

Fifty-three asthmatic children, with a mean age of 9 years (range 4 years to 14 years), who were followed at the pediatric allergy clinic of the Chang Gung Children's Hospital were enrolled in this study. A detailed history of allergies and a complete physical examination were carried out by a pediatrician and a otolaryngologist for each patient. All 53 patients demonstrated symptoms of sinusitis at the time of radiographic studies. These symptoms included chronic cough, persistent anterior-posterior rhinorrhea, nasal congestion, headache, and chronic otitis media. Physical signs included periorbital edema, nasal mucosal edema, mucopurulent rhinorrhea, and wheezing. Appropriate informed consent from the parents of each patient was obtained after it was explained that radiography was clinically indicated as a diagnostic procedure and there would be no charge for the procedure.

### Standard radiography and computed tomography

Occipitomental (Waters'), occipitofrontal (Caldwell), and lateral views of the paranasal sinuses were performed for all patients. All sinus X-rays films were read by one experienced radiologist blinded to the clinical information. Positive radiographic examination criteria were defined before beginning the study as demonstrating abnormalities of one or all of the following, $\geq 4$ mm of mucosal thickening, any degree of opacification of one or more sinuses, and an air-fluid level.[3-5,11] All patients also received modified and limited prone coronal CT scans at selective maxillary, sphenoidal, and fronto-ethmoidal sinuses, respectively, with a slice thickness of 3 mm to minimize radiation doses. Prone coronal CT scans gave more information about the nasal lateral wall and made it much easier to differentiate between anterior and posterior ethmoidal cell involvement than transaxial sections. These were interpreted by an experienced radiologist who was not provided with any medical history or clinical information about the patients. Mucosal thickening was interpreted as mucosal lining wider than 4 mm.

### Statistics

With CT as the standard, we calculated sensitivity and specificity for sinus X-rays films as follows: sensitivity = TP/(TP + FN) and specificity = TN/(TN + FP), where TP is true positive, TN is true negative, FP is false positive, and FN is false negative.

## RESULTS

All patients had ethmoidal and maxillary sinus development. Those patients with frontal and sphenoidal sinus developmental are listed in Table 1. The findings of standard radiography in paranasal sinuses were compared with prone coronal CT of 53 asthmatic children (aged listed in Table 1), representing sensitivity of 81.1%, 51.8%, 47.3%, 40.8% and specificity of 72.7%, 84.8%, 87.2%, 93.3% for maxillary, ethmoidal, frontal, and sphenoidal sinuses, respectively (Table 2). Involvement of different sinuses detected using CT scans are shown in Table 3. The proportion of patients presenting with sinus disease was higher in the younger children

**Table 1** Development of frontal and sphenoidal sinuses as determined using CT in a population of 53 asthmatic children related to age group.

| Age group (years) | Number | Sphenoidal | Frontal |
|---|---|---|---|
| 4-6 | 7 | 5 (71%) | 2 (29%) |
| 6-8 | 14 | 11 (79%) | 7 (50%) |
| 8-10 | 14 | 13 (93%) | 12 (86%) |
| > 10 | 18 | 16 (89%) | 17 (94%) |

(age 4 to 8 years) than in the older children. The percentage of children with maxillary sinusitis, detected using CT scans, was about 50% to 70% in all age groups, but in younger children (4 to 8 years), the disease was more severe with a higher degree of opacity and more frequent bilateral disease. The relative frequency of sinusitis in the frontal, ethmoidal, and sphenoidal sinuses tended to fall with increasing age (Table 3). Of the 53 patients studied, 31 (58%) had an abnormality of a sinus on CT scans. The abnormality in any of the paranasal sinuses and of the maxillary sinuses detected using CT and standard radiography were 64%, 58% and 71%, 68%, respectively. Our study also showed that standard radiography missed approximately 13% - 24% of the abnormal sinuses found on CT. In 21 (40%) of the 53 patients, discrepancies were seen between the interpretations of standard radiography and those of CT scans. The findings are shown in Table 4.

**Table 2** Sensitivity and specificity of various sinusitis detected using standard radiography compared to computed tomography

| | TP | TN | FN | FP | Sensitivity (%) | Specificity (%) |
|---|---|---|---|---|---|---|
| **Maxillary sinuses** | 43 | 40 | 8 | 15 | 81.1 | 72.7 |
| **Ethmoidal sinuses** | 14 | 67 | 13 | 12 | 51.8 | 84.8 |
| **Frontal sinuses** | 9 | 50 | 10 | 7 | 47.3 | 87.2 |
| **Sphenoidal sinuses** | 6 | 70 | 9 | 5 | 40.8 | 93.3 |

TP: true positive; TN: true negative; FN: false negative; FP: false positive.

**Table 3** The occurrence of sinusitis of various paranasal sinuses, related to age group, detected using CT in 53 asthmatic children

| Age group (years) | Sinus disease | Maxillary | Ethmoidal | Frontal | Sphenoidal |
|---|---|---|---|---|---|
| 4-6 (N = 7) | 85% | 71% | 43% | ND* | 28% |
| 6-8 (N = 14) | 78% | 70% | 71% | 57% | 14% |
| 8-10 (N = 14) | 64% | 57% | 42% | 28% | 21% |
| > 10 (N = 18) | 45% | 45% | 11% | 6% | 6% |

*ND: not yet developed

**Table 4** Results of standard radiography and CT of paranasal sinuses

| | Maxillary | Ethmoidal | Frontal | Sphenoidal |
|---|---|---|---|---|
| **Number of sinuses evaluated** | 106 | 106 | 76 | 90 |
| **Discrepancies between interpretation of standard radiography and CT scans** | 23 (22%) | 25 (24%) | 17 (22%) | 4 (13%) |
| **Number of patients with abnormal sinuses on standard radiography** (N=53) | 36 (70%) | 18 (34%) | 10 (19%) | 7 (13%) |
| **Number of patients with abnormal sinuses on CT scan** (N=53) | 31 (58%) | 21 (40%) | 13 (25%) | 8 (15%) |

## DISCUSSION

The paranasal sinuses are four paired structures surrounding the nasal cavities. Developmently, the maxillary and ethmoidal sinuses are present at birth and are evident using radiography during infancy. The development and radiographic appearance in sphenoidal and frontal sinuses are shown later. The youngest patient with sphenoidal sinus development was 1 year 10 months old.[12] In our 53 patients, no development of sphenoidal sinuses on CT was noted in eight patients and of frontal sinuses in 15 patients (Table 1).

Slavin *et al.*[7,13] reported that 53% to 75% of children with asthma have abnormal sinus radiographs. Brent and David[14] found that accurate and appropriate diagnosis of chronic sinusitis in asthma patients followed by effective treatment improved both patients' sinus condition and asthma in approximately 70% to 80% of the patients. Although the importance of evaluating the sinuses in patients with asthma is well documented, we have to deal with two problems, the prevalence rate of sinusitis in asthmatic children and the confidence in the diagnosis of sinus disease using plain radiography. It has been suggested that plain radiography may underestimate or overestimate sinus disease. Therefore, we prospectively compared sinus radiographs with prone coronal CT scans.

The most commonly employed means of evaluating sinus disease is plain radiography. The occipitomental (Waters') view is used for delineation of the maxillary sinuses, and the lateral view is used for observation of the sphenoidal and frontal sinus. The anteroposterior view is used to visualize the frontal and ethmoidal sinuses. Air-fluid levels and opacification are considered to be reliable pathologic findings on plain X-rays. Some authors also consider mucosal thickening of 4 mm or more to be a reliable pathologic finding.[4,5,11] A CT scan gives a much better visualization than does a plain X-ray of the anatomy of the bone and mucous membranes of the paranasal sinuses and has become the standard for sinus imaging.[15] To reduce radiation doses, we developed a modified and limited CT scanning protocol using 3 mm thickness and single slice at maxillary, sphenoidal, and fronto-ethmoidal sinuses, respectively.

In the study by Rachelefsky *et al.*[5,16] and others,[4,17] the maxillary sinuses were most commonly involved (as in the present study, Table 2). The severity of maxillary sinusitis tends to fall with increasing age (Table 2). Gwaltney *et al.*[18] showed, using CT scanning, that maxillary, ethmoidal, frontal and sphenoidal sinus abnormalities in the patients with common colds were 87%, 65%, 32%, and 39%, respectively. The data of Zimmerman *et al.*[19] in the examination of 138 asthmatic children using sinus X-rays revealed that abnormal maxillary, ethmoidal and frontal sinus were 94%, 28% and 8%, respectively. The overall prevalence of paranasal sinusitis found using radiography is very similar to our results.

Standard radiography in our study showed that both the sensitivity (81.8%) and specificity (72.7%) were satisfactory for maxillary sinuses. The relatively lower sensitivity for evaluation of sinus disease using plain radiography was seen in ethmoidal, frontal and sphenoidal sinus (Table 2). Lee *et al.*[20] in examination of 33 children suggested of having chronic sinusitis, found maxillary sinuses are well visualized on radiographs using Waters' view. Rudolf *et al.*[21] reported that the standard Waters' view radiograph was employed as a first-line screening method for the paranasal sinuses. Our results revealed that maxillary sinus radiography had a reasonable degree of confidence in the diagnosis of sinusitis.

McAlister *et al.*[22] reported that 80% of the sinus CT scans were abnormal in 70 infants and children with recurrent sinusitis. Havas *et al.*[23] stated the prevalence of abnormal sinus CT scans was 54.4% in asymptomatic patients with allergic rhinitis. Of the 53 patients in our study, 31 (58%) had abnormalities of the sinuses shown on prone coronal CT scans. Our study also showed that standard radiography missed approximately 13% - 24% of abnormal sinuses found on CT (Table 4). In 21 (40%) of the 53 patients, discrepancies were seen between the interpretations of standard radiography and those of CT scans. Wippold *et al.*[24] reported that the discrepancy rate in adults between plain radiography and prone coronal CT was 59%. Lusk *et al.*[25] and Davidson *et al.*[26] found that comparison of plain film radiography and CT imaging of different sinuses showed discrepancies that ranged from 23% to 74%. Caffy[27] advised caution in interpreting the results of the sinus radiographs of children because of certain variations, such as asymmetry in facial bones, sinus development, overlying soft tissues.

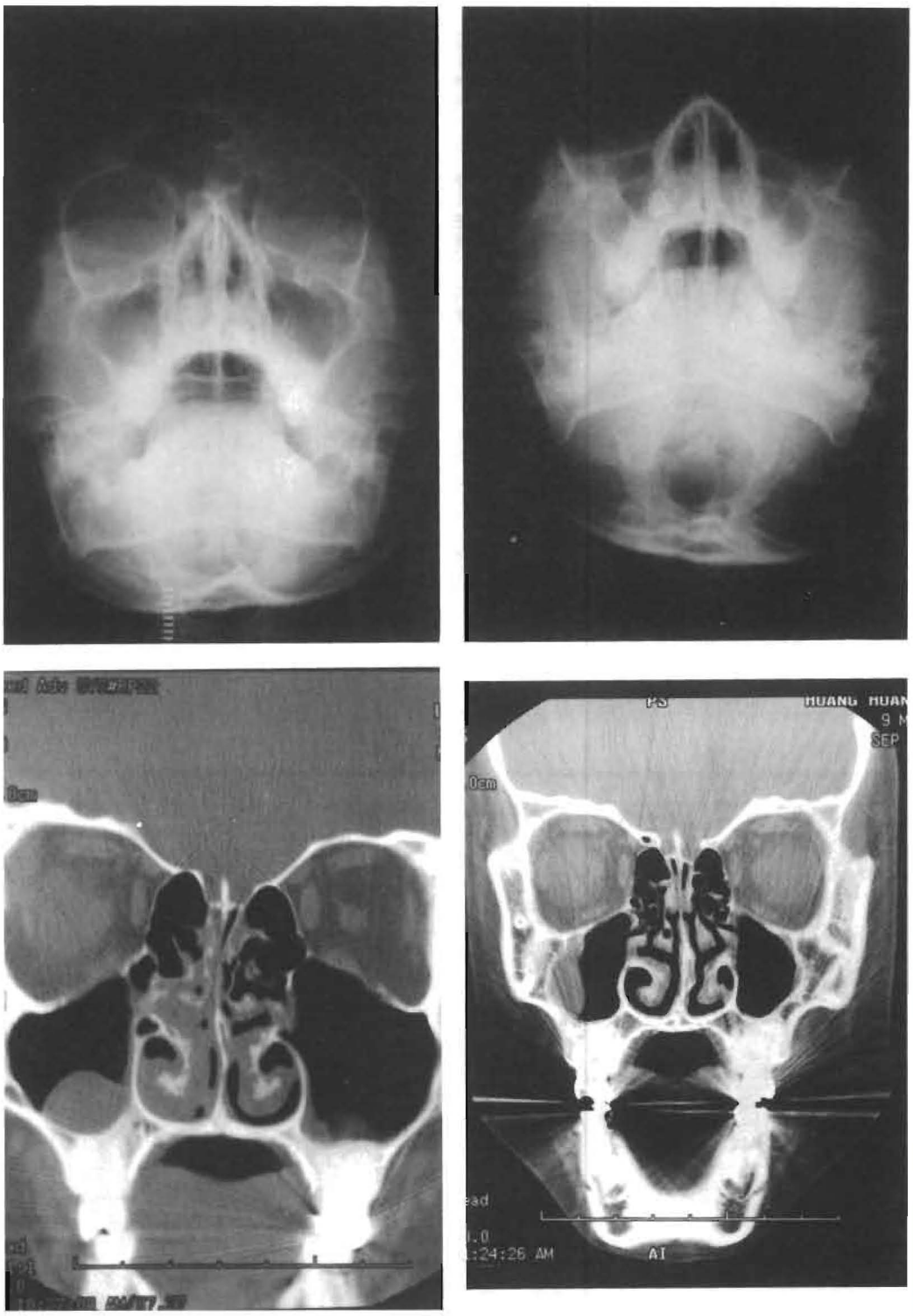

**Fig. 1** Waters' view of a 14-year-old boy (A) and a 9-year-old boy (B) show partial opacification of right maxillary sinus in these two patients. Representative CT scans show bilateral retention cyst (C) and right retention cyst (D).

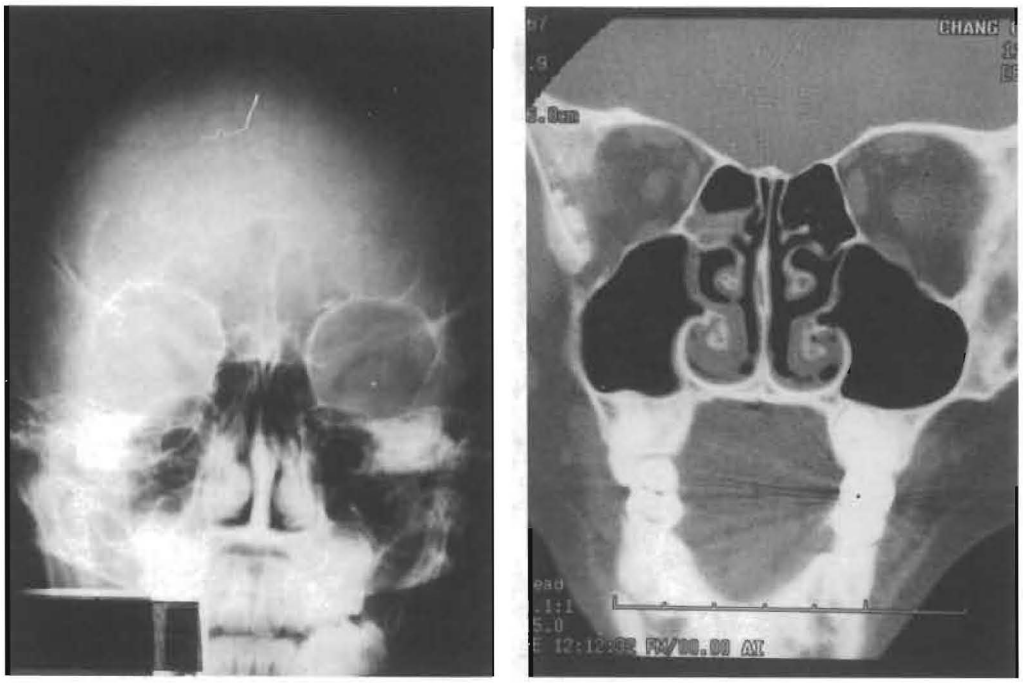

**Fig. 2** A: Caldwell projection radiograph in an 8 year-old girl was interpreted as showing normal ethmoidal sinuses bilaterally; B: Representative coronal CT scan shows abnormal right ethmoidal sinus.

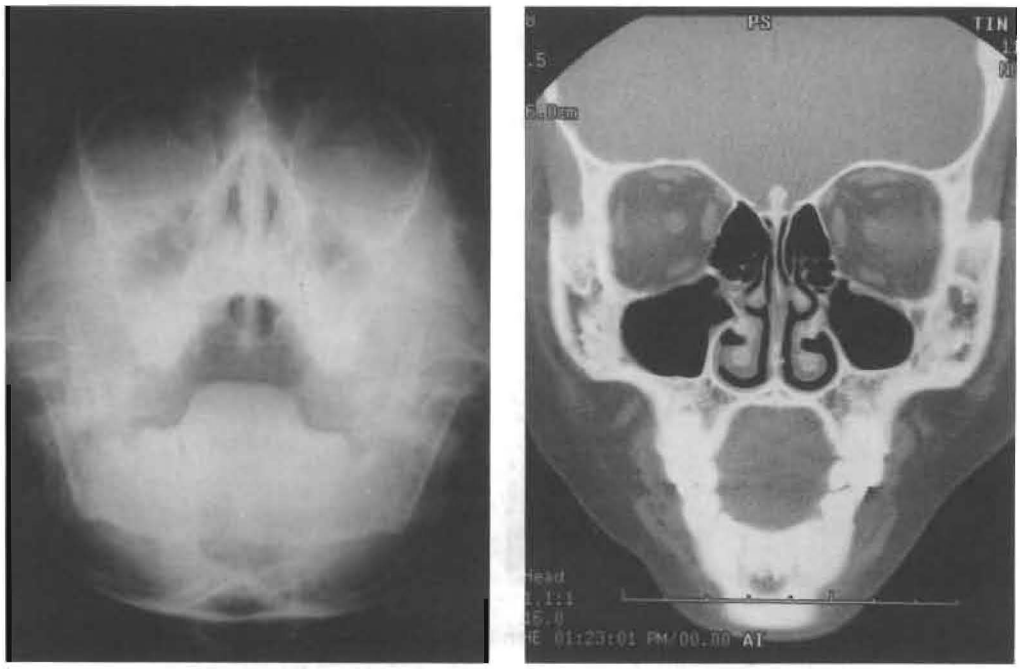

**Fig. 3** A: Waters' view of a 10 year-old boy shows mucosal thickening of maxillary sinuses; B: Representative CT scan is normal.

The agreement between plain radiographs and CT scans was the best in evaluating the maxillary sinus,[16] although minimal to modest mucous membrane thickening, especially posteriorly or posterior retention cysts, may not be evident on plain radiographs (Fig. 1). Partial ethmoidal disease noted on CT scans may not be shown on conventional radiographs (Fig. 2). Some maxillary sinuses that appeared as mucosal thickening on plain radiographs were misinterpreted to be maxillary sinusitis (Fig. 3). Lazar *et al.* [8] demonstrated that plain radiography of the sinuses may lead to underdiagnosis or even overdiagnosis of sinus disease in children. In the study by McAlister *et al.* [22] plain radiography was valuable in the evaluation of sinus disease in children, but did show limitations particularly of the ethmoidal and sphenoidal sinus.

The charges for CT in our institution are substantially greater than for plain radiographs. The cost of limited coronal CT series at our institution is $117 (includes professional and technical fees) which should be compared with $16 for a plain film sinus series. Approximately 1.2 centiGray (1 centiGray = 1cGy = 1 rad ) is given for plain film radiography (three projections). This is compared with 4.8 to 5.6 cGy (multiple scan average dose)[28] for CT scans.

Our study demonstrated that X-rays of the maxillary sinus had a higher value of sensitivity than X-rays of other sinuses for detecting occult chronic sinusitis. Standard radiography is inexpensive and simple to use. Standard radiography of maxillary sinuses may be useful as a first-line screen modality for occult chronic sinusitis in asthmatic children.

**REFERENCES**


1. Friday GA, Fireman PH. Sinusitis and asthma: clinical and pathogenic relationships. Clin Chest Med 1988; 9: 557-65.
2. Silk HT. Sinusitis and asthma: a review. J Asthma 1990; 27: 1-9.
3. Haung JL, Lin TY, Wang KF. Sinusitis and bronchial asthma in children. Acta Paed Sin 1995; 36: 20-3.
4. Friedman R, Ackerman M, Wald E, Casselbrant M, Friday G, Fireman P. Asthma and bacterial sinusitis in children. J Allergy Clin Immunol 1984; 74: 185-9.
5. Rachelefsky GS, Katz RM, Siegel SC. Chronic sinus disease with associated reactive airway disease in children. Pediatrics1984; 73: 526-9.
6. Mcfadden ER. Nasal-sinus-pulmonary reflexes and asthma. J Allergy Clin Immunol 1986; 78: 1-4.
7. Slavin GS, Cannon RE, Friedman WH, Palitany E, Sundaram M. Sinusitis and bronchial asthma. J Allergy Clin Immunol 1980; 66: 250-7.
8. Lazar RH, Younis RT, Parvey LS. Comparison of plain radiographs, coronal CT, and intraoperative finding in children with chronic sinusitis. Otolaryngol Head Neck Surg 1992; 107: 29-34.
9. Younis RT, Lazar RH. The approach to acute and chronic sinusitis in children, Ear Nose Throat J 1991; 70: 35-94.
10. Druce HM. Emerging techniques in the diagnosis of sinusitis: Ann Allergy 1991; 66: 132-6.
11. Shapiro GG, Furukawa CT, Pierson WE, Gilbertson E, Bierman CW. Blinded comparison of maxillary sinus radiography and ultrasound for diagnosis of sinusitis. J Allergy Clin Immunol 1986; 77: 59-64.
12. Fujioka M, Young LW. The sphenoidal sinuses: radiographic patterns of normal development and abnormal finding in infants and children. Radiology 1978; 129: 133-6.
13. Slavin RG. Sinupulmonary relationships. Am J Otolaryngol 1994; 15: 18-25.
14. Brent AS, David WK. Management of sinusitis in the asthmatic patients. Ann Allergy Asthma Immunol 1996; 77: 6-19.
15. Zinreich J. Imaging of inflammatory sinus disease. Otolaryngol Clin North Am 1993; 26: 535-47.
16. Rachelefsky GS, Goldberg M, Katz RM, Boris G, Gyepes MT, Shapiro MT, Mickey MR. *et al.* Sinus disease in children with respiratory allergy. J Allergy Clin Immunol 1978; 61: 310-4.
17. Slavin RG. Relationship of nasal disease and sinusitis to bronchial asthma. Ann Allergy 1982; 49: 76-80.
18. Gwaltney JM, Phillips CD, Miller RD, Riker DK. Computed tomography study of the common cold. N Engl J Med 1994; 330: 25-30.
19. Zimmerman B, Stringer D, Feanny S, Reisman J. Hak H, Rashed N. Prevalence of abnormalities found by sinus X-ray in childhood asthma: lack of relation to severity of asthma. J Allergy Clin Immunol 1987; 90: 268-73.
20. Lee HS, Majima Y, Sakadura Y, Inagaki M, Sugiyama Y, Nakamoto S. Conventional X-ray versus CT in diagnosis of chronic sinusitis in children. Nippon Jibiinkoka Gakkai Kaiho 1991; 94:1250-6.
21. Pfister R, Lutolf M, Schapowal A, Glatte B, Schmitz M, Menz G. Screening for sinus disease in patients with asthma: A computed tomography-controlled comparison of A-mode ultra-sonography and standard radiography. J Allergy Clin Immunol 1994; 94: 948-9.
22. McAlister WH, Lusk R, Muntz HR. Comparison of plain radiographs and coronal CT scans in infants and children with recurrent sinusitis. Am J Roentgenol 1989; 153: 1259-64.
23. Havas TE, Motby JA, Gullane PJ. Prevalence of incidental abnormalities on computed tomographic scans of the paranasal sinuses. Arch Otolaryngol Head Neck Surg 1988; 114: 856-9.
24. Wippold FJ, Levitt RG, Evens RG, KorenblatPZ, Hodge FJ, Tost RG. Limited coronal CT: An alternative screening examination for sinonasal inflammatory disease. Allergy Proc 1995;16: 165-9.
25. Lusk R, Lazar R, Muntz M. The diagnosis and treatment of recurrent and Chronic sinusitis in children. Pediatr Clin North Am 1989; 36: 1411-21.
26. Davidson T, Brahmer F, Gallaher M. Radiographic evaluation for nasal dys-

function-CT versus plain films. Head Neck 1989; 11: 405-9.
27. Caffey J. Pediatric X-ray diagnosis. 6th ed. Chicago: Mosby Year Book. 1972; pp. 104-11.
28. McCrohan JL, Patterson JF, Gagne RM, Goldstein HA. Average radiation doses in a standard head examination for 250 CT systems. Radiology 1987; 163: 263-8.