The Accuracy of Limited CT in the Evaluation of Chronic Rhinosinusitis and for Endoscopic Sinus Surgery: A Multicenter Study

Pongsakorn Tantilipikorn, M.D.*, Anchalee Churojana, M.D.**, Pipat Chiewwit, M.D.**, Warinthorn Phuttharak, M.D.***,

Sukalaya Lerdlum, M.D.****, Songklot Aeumjaturapat, M.D.*****, Sanguansak Tanaviratananich, M.D.******,

Paraya Assanasen, M.D.*, Chaweewan Bunnag, M.D.*

*Department of Otorhinolaryngology, **Department of Radiology, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand, ***Department of Radiology, Faculty of Medicine, Khon Kaen University, Khon Kaen 40002, Thailand, ****Department of Radiology, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand, *****Department of Otorhinolaryngology, Faculty of Medicine, Khon Kaen University, Khon Kaen 40002, Thailand, ******Department of Otorhinolaryngology, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand.

ABSTRACT

Objective: To compare the accuracy of Limited CT with the Full CT as the standard evaluation for inflammatory disease of PNS and the identification of anatomical variations.

Methods: From Full CT of PNS, Limited CT were retrieved. Computerized tomographic scans were performed for the preoperative planning of endoscopic sinus surgery (ESS) in 3 tertiary care university hospitals in Thailand. The two types of examinations were reviewed independently and in random order by two experienced radiologists. Using Full CT as the standard, the accuracy of Limited CT were evaluated for 1) the radiologic staging of rhinosinusitis (Lund-Mckay scoring system) and 2) the anatomic variations which are an important landmark for surgical operations in rhinosinusitis.

Results: Totally 132 patients were included. Two hundred and sixty four half-faces were reviewed. Lund-McKay radiographic sinus staging system showed 97-99% specificity except for the ostiomeatal complex region. Regarding anatomic variation, Limited CT was able to yield accurate results for the frontal cell type II-IV, Haller cell, Agger nasi cell, paradoxical middle turbinate, concha bullosa and the protrusion of the optic nerve.

Conclusion: Limited CT can be used as a surgical roadmap for the cases with the anterior group of sinus involvement. It may be utilized for surgical planning of chronic CRS involving the anterior group of sinuses. For the posterior group of sinuses, it may not yield enough accuracy and the standard Full CT should be requested to prevent erroneous estimation.

Keywords: Anatomical variation, chronic rhinosinusitis, computed tomography scan, endoscopic sinus surgery

Chronic rhinosinusitis (CRS) prevalence is increasing in Thailand as through out the world. The pathophysiological mechanisms of CRS are most likely multifactorial and therefore, many controversies and problems remain in both diagnosis and treatment. The cost of special investigations and treatments of CRS are high and of major concern in countries with low social-economical status.

In Thailand, we use Clinical Practice Guidelines (CPG) for the diagnosis of CRS.[1] From the data registry of CRS, which was conducted by seven Otorhinolaryngological training centers in Thailand, the cost of computerized tomography scan (CT scan) of the paranasal sinuses (PNS) represents about 15% of the total cost of CRS patients' care and is in the second place after the cost of antibiotics.[2]

The purposes of CT scan imaging of the PNS in CRS are the evaluation of inflammatory staging, and the identification of the anatomical variations. These anatomical variations are closely related with the vital

structures such as orbits, brain, optic nerves and internal carotid arteries. Thus, the CT scan of PNS is a surgical roadmap that is necessary preoperatively for avoiding the potential catastrophic complications which may occur during endoscopic sinus surgery (ESS).

The quality of the PNS imaging by CT scan is directly related to the performance of the scanner available. Full CT scan, which is considered as a standard imaging tool, provides slides from both axial and coronal planes every 3-5 mm with or without contrast medium injections. Limited CT scan, reveals slides from the coronal plane only.

The limited coronal CT study has become the best accuracy assessment of the osteomeatal unit and is designed to limit the patient's radiation dose. In general, patients are positioned prone with head hyperextended on the scanner bed. A scan plane is perpendicular to the hard palate and the studies are routinely obtained as 3-mm-thick contiguous slices.[3] Spiral CT is now a viable alternative technique to the conventional multi-slice approach, where the faster spiral CT minimizes patient motion. In addition, the advance multidetector CT scanner allows excellent coronal images or any desired angle to be created from images made in the axial plane. In addition, this technique provides the advantage of speed and the ability to generate very thin images while producing least radiation dose.[4]

By using limited CT, or direct coronal scanning from a conventional CT machine, the patient is exposed to less radiation and costs 3 times less money compared to Full CT (60 vs. 150 US Dollars)[3]. For the screening of patients with presumptive CRS, a sensitivity of 93.3% and a specificity of 89.3% of limited CT were observed[6]. However, there is yet no study available regarding the accuracy of limited CT for inflammation staging of the PNS and the identification of anatomical variations for preoperative planning in ESS.

The objective of this study was to evaluate the sensitivity and specificity of coronal CT in the preoperative planning of ESS by using full CT as the gold standard. The sensitivity and specificity were assessed by the accuracy of the radiological staging of inflammation in CRS (Lund-Mckay scoring system) and by the correct identification of the anatomical variations which are important to be identified before ESS.

MATERIALS AND METHODS

This is a prospective comparative multi-center study conducted in 3 otorhinolaryngological training centers in Thailand: 1) Mahidol University, Siriraj Hospital, 2) Chulalongkorn University Hospital, and 3) Khon Kaen University Hospital. The study was approved by the human right and ethical committee from each center.

Patients with chronic rhinosinusitis (CRS) who were scheduled to undergo ESS were included. Exclusion criteria were 1) CRS with previous operations, 2) CRS with complication, and 3) sinonasal tumor or trauma. The data of Limited CT were created from the data of Full CT.

Examination Protocol: The studies were performed by multidetector CT scanners using 1.2-mm-thick slice. Reconstruction in the coronal plane was perpendicular to the hard palate with 2-mm-thick images from the anterior wall of the frontal sinus through to the posterior wall of the sphenoid sinus. Axial image refor-

mations were made at 5 mm thick.

The image display highlights the air passages, the bony detail and the soft tissues by setting parameters with an averaged window width of 1,800-2,000 Houndsfield units (HU) and an averaged level of 250-300 HU.

The dose report defined as computed tomography dose index (CTDI) which was automatically calculated by the machine averaged at 40-70 mGy.

Each CT scan was interpreted by two neuroradiologists. Standardization process between two readers was done, and the Kappa analysis was calculated as the value above 0.8 in order to prevent inter-observer variability. By using Full CT as a standard, each Limited CT was analyzed separately in half-heads. The name and hospital number of patients on scans were masked by placing an opaque sticker to prevent intra-rater bias.

Scoring system for CT PNS: The study parameters were: 1) Lund-McKay scoring: for evaluating the extension of CRS inflammatory lesions (Table 1), 2) anatomical variations which were important landmarks before the ESS operation (Table 2).

Statistical analysis

The comparative results were analyzed by paired t-test and the prevalence of anatomical variations was reported as a percentage with 95% confidence interval (CI).

RESULTS

One hundred and fifty patients were included. Eighteen patients were excluded because the quality of the CT scans did not match with the standard cutting criteria. Then, 132 scans, separated into 264 sides were evaluated.

The accuracy of Limited CT, defined by the ability to detect various anatomical structures or variations, was shown in Table 1. In comparison with Full CT, the accuracy of Limited CT was approximately 90% except for the sphenoethmoidal cells, the protrusion of the internal carotid artery and the skull base type I-II (according to Keros's).[7] The specificity of Limited CT for detection of the sphenoethmoidal cells was 75.21%, and for the protrusion of the internal carotid artery and the skull base type II-III were 79.69 and 72.90-75.19%, respectively.

The accuracy of Limited CT for detection of the inflammatory staging of CRS, defined by the Lund-McKay Scoring system, was shown in Table 2. Limited CT showed the high specificity for all sinuses scoring, but low specificity for the ostiomeatal complex region.

Table 3 showed the prevalence of all anatomical variations found in this study. The absence of the frontal sinus was observed in 6.06% of the cases (95% CI 3.50-9.66%). The agger nasi cell was present in 78.03% of cases (95% CI 72.55-82.87%), Haller's cell in 12.50% of cases (95% CI 8.76-17.10) and Onodi cell in 8.33% of cases (95% CI 5.30-12.34%).

Concha bullosa (pneumatization of the middle turbinate) was found in 23.48% of cases (95%CI 18.51-29.07%). A paradoxical bending of the middle turbinate was detected in 2.27% of cases (95%CI 0.84-4.88%).

According to the skull base classification by Keros, the skull base type II was the most common type (51.14%), followed by type III and type I respectively. The protrusion of the internal carotid artery into the

TABLE 1. Specificity and sensitivity of limited CT as compared to full CT in identifying anatomic variations (n=264).

	Matched (Sensitivity)	Matched (Specificity)	Sensitivity (95% CI)	Specificity (95% CI)
1. Type of skull base (Keros)	80	113	73.39% (64.07%,81.40%)	72.90% (65.19%,79.72%)
Type I				
Type II	72	97	53.33% (44.56%,61.96%)	75.19% (66.82%,82.37%)
Type III	5	219	31.25% (11.02%,58.66%)	88.31% (83.64%,92.03%)
2. Onodi cell	8	182	36.36% (17.20%,59.34%)	75.21% (69.27%,80.51%)
3. Protrusion of optic nerve	13	216	33.33% (19.09%,50.22%)	96.00% (92.54%,98.15%)
4. Protrusion of internal carotid artery	4	204	50.00% (15.70%,84.30%)	79.69% (74.23%,84.44%)
5. Concha bullosa	46	195	74.19% (61.50%,84.47%)	96.53% (92.99%,98.60%)
6. Paradoxical middle turbinate	3	249	50.00% (11.81%,88.19%)	96.51% (93.48%,98.39%)
7. Haller's cell	7	224	21.21% (8.98%,38.91%)	96.97% (93.86%,98.77%)
8. Agger nasi cell	100	52	48.54% (41.54%,55.59%)	89.66% (78.83%,96.11%)
9. Absent frontal sinus	9	244	56.25% (29.88%,80.25%)	98.39% (95.92%,99.56%)
10. Frontal cell	17	149	32.08% (19.92%,46.32%)	70.62% (63.97%,76.67%)
Type I				
Type II	1	240	7.69% (0.19%,36.03%)	95.62% (92.29%,97.79%)
Type III	0	251	0.00% (0.00%,30.85%)	98.82% (96.59%,99.76%)
Type IV	0	212	0.00% (0.00%,70.76%)	99.53% (97.41%,99.99%)

sphenoid sinus was found in 3.03% of cases (95% CI 1.32-5.88%). The protrusion of the optic nerve was found in 14.77% of cases (95% CI 10.72-19.64%).

DISCUSSION

Since the introduction of ESS in the late seventies, CT scan has been considered as a standard radiological tool for the diagnosis and the evaluation of paranasal sinuses anatomy[8]. It does not only provide information about sinonasal inflammatory and non-inflammatory pathology for the otorhinolaryngologists, but also the data necessary to form a tailored, definitive surgical approach.[9-10] This technique delineated areas poorly shown on conventional x-ray films, such as the anterior ethmoid cells, the osteomeatal complex, and the middle turbinates.[11] The other anatomic variations such as concha bullosa, sphenoethmoidal cell, infraorbital cell, protrusion of internal carotid artery and optic nerve are clearly demonstrated. With this reason, Full CT has been declared by some authors as the gold-standard radiograph for evaluation of the paranasal sinuses diseases.[12]

Concerning radiation exposure, in phantom studies performed with exposure of 125 kVp and 80-160 mAs, a lens dose of 14 mGy was measured for scanning the paranasal sinuses in either the axial or coronal position, and the radiation dose equivalent or effective dose was

TABLE 2. Specificity and sensitivity of Limited CT as compared to Full CT by using Lund-McKay scoring system (n=264).

	Matched (Sensitivity)	Matched (Specificity)	Sensitivity (95% CI)	Specificity (95% CI)
Frontal	63	189	87.50% (77.59%,94.12%)	98.44% (95.50%,99.68%)
Anterior ethmoid	53	195	84.13% (72.74%,92.12%)	97.01% (93.62%,98.90%)
Posterior ethmoid	22	232	73.33% (54.11%,87.72%)	99.15% (96.95%,99.90%)
Maxillary	34	210	66.67% (52.08%,79.24%)	98.59% (95.94%,99.71%)
Sphenoid	20	230	66.67% (47.19%,82.71%)	98.29% (95.68%,99.53%)
Ostiomeatal complex	88	127	92.63% (85.41%,96.99%)	75.15% (67.93%,81.46%)

TABLE 3. Prevalence of anatomic variations (n=264).

Anatomic variations	Prevalence	95% CI
Skull base type I	41.29%	(35.29%,47.49%)
Skull base type II	51.14%	(44.93%,57.31%)
Skull base type III	6.06%	(3.50%,9.66%)
Onodi cell	8.33%	(5.30%,12.34%)
Protrusion of optic nerve	14.77%	(10.72%,19.64%)
Protrusion of internal carotid artery	3.03%	(1.32%,5.88%)
Concha bullosa	23.48%	(18.51%,29.07%)
Paradoxical middle turbinate	2.27%	(0.84%,4.88%)
Haller's cell	12.50%	(8.76%,17.10%)
Agger nasi cell	78.03%	(72.55%,82.87%)
Absent frontal sinus	6.06%	(3.50%,9.66%)
Frontal cell type I	20.08%	(15.41%,25.42%)
Frontal cell type II	4.92%	(2.65%,8.27%)
Frontal cell type III	3.79%	(1.83%,6.86%)
Frontal cell type IV	1.39%	(0.29%,4.01%)

Fig 2. Full CT shows indentation of internal carotid artery that can be missed if using coronal plane without axial plane. ( ).

approximated at 1.76-2.88 milli-Sievert (mSv) which varies linearly with mAs.[13] For our data, the total dose of scanning was 40-70 mGy which was converted to be an effective dose at an average of 1.38-2.76 mSv.[14] Duvoisin B, et al. recommended the use of low-dose (30-60 mA) CT for evaluation of inflammatory disease of the sinus.[15] Because the coronal image of limited CT in this study was generated from the very thin slices made by the axial plane (to avoid the two scanning protocol in the same patient), the actual dose of limited CT in this study was calculated, not the actual measurement. However, if the limited CT was done in a separate scan, the dose of limited CT will actually be less than the total dose in this study.

In Thailand, the cost of full CT ranges from 4,500-6,000 baht (~150 USD) while the cost of limited CT ranges from 2,000-2,500 baht (60-75 USD). The use of full CT scan in the evaluation of CRS, a disease with increasing prevalence, has become a major burden of health care expenditures. Limited CT seems to be a

reasonable alternative. It costs only 1/3 of full CT. Limited CT provides a sensitivity of 93.3% and a specificity of 89.3% for the screening examination.[6] However, for the utilization of limited CT in preoperative planning, some endoscopic surgeons would not be willing to use it because of the possibility of erroneous diagnosis leading to either excessive or inadequate treatment of a patient.[16]

Limited CT yields high specificity (95.5-99.5%) for the frontal cell type II-IV, but only 70.1% for the frontal cell type I. This may be explained by the non-contiguous character of Limited CT which may skip the only one frontal cell (so called type I) above the agger nasi, but the 2-4 frontal cells above the agger nasi are unlikely to be overlooked. This explanation may be due to the shape of skull base according to Keros's classification. Limited CT shows higher specificity (88.3%) for the deeper type of skull base (type III), comparing to the type I. The less difference of distance between the skull base and olfactory fossa (Keros's type I: 1-3 mm) may be overlooked by the limited CT, but the more difference (Keros's type III: more than 8 mm. difference) is unlikely to be missed.

In terms of the accuracy of limited CT for identification of the sites of inflammation, it also shows high
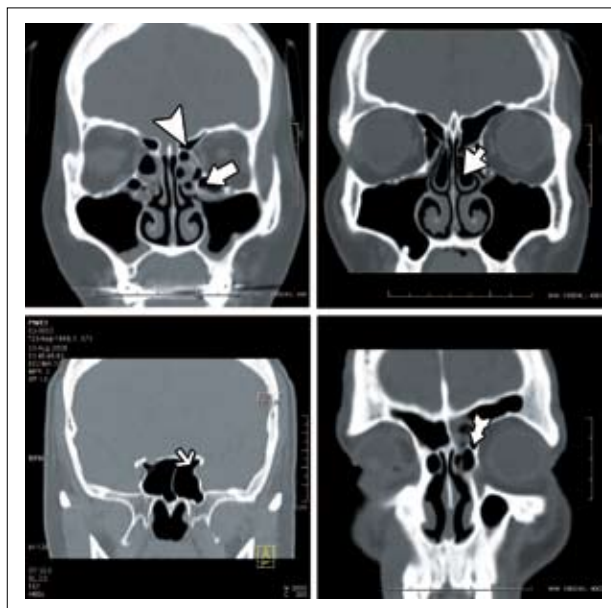

Fig 1. Coronal CT from series of Limited CT shows: Keros III ( ), Infraorbital cell ( ), Concha bullosa ( ), Protrusion of ICA and CN II ( ), Agger nasi & Frontal cell type I ( ).
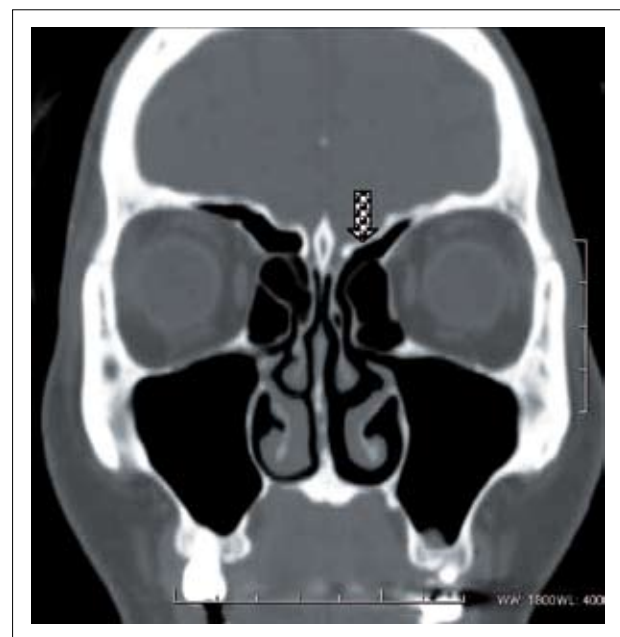

Fig 3. Coronal plane of skull base on the left side which is difficult to categorized whether type I (3 mm) or type II (4 mm). ( ).

specificity (97-98.6%) when using the Lund-MacKay scoring system. The 75.1% specificity of limited CT at the ostiomeatal complex area may be explained by the scoring system at this area has 0 and 2 only, comparing with 0, 1, 2 for the other sinuses/areas. Then, when using the coronal plane without the axial plane, the slightly mucosal thickening may be over-interpreted. In terms of sensitivity of the ostiomeatal complex, it reaches 92.6%. This means that if there is inflammation shown by full CT, the limited CT has a high opportunity to detect that lesion. The present data are in agreement with previous studies.[9,10,12,17]

Another finding in this study was the prevalence of anatomic variations. The report of single center study in Thailand was published by Nittinavakarn and Thanaviratananich in 2005.[16] This multicenter study, using limited CT, shows the comparable prevalence to the other reports.

The agger nasi cell was detected in 78% of cases, comparable to Bolger WE, et al (89%).[17] The prevalence of Haller's cell (infraorbital ethmoid) was 12.5% of cases (comparable to Nittinavakarn and Thanaviratananich[18] 23.8%). The reported prevalence of concha bullosa was 34.1% of cases.[11] This study shows 23.5% of conch bullosa cases. The most common type of skull base in this study was type II (51.1%), followed by type III (6.1%) and type I (41.3%), comparable to Keros's study.[7]

CONCLUSION

This multicenter study of limited CT has shown the high specificity compared with Full CT in the preoperative evaluation of inflammatory staging of CRS and detection of anatomical variation in patients who needed ESS. Although the multidetector scanner has become the scanner of choice for imaging the sinunasal cavities due to its advantage of refined reconstructions in planes other than the primary scan plane, in the places where it is not available, we recommend to use limited CT protocol using direct coronal scan to minimize radiation exposure and cost. The endoscopic surgeon should use limited CT for the case of the anterior group of sinus involvement. For the posterior group involvement, limited CT may not yield enough accuracy and the standard full CT should be requested for preventing erroneous estimation.

ACKNOWLEDGMENTS

REFERENCES

1. Bunnag C, Thanaviratananich S, Teeratakulpisan C, et al. Clinical practice guideline for rhinosinusitis in Thais. Siriraj Med J 2003;55:1-27.
2. Assanasen P, Bunnag C, Tunsuriyawong P, et al. Rhinosinusitis Registry in Thailand. Siriraj Med J 2005;57(Suppl 1):105-6.
3. Zinreich SJ, Gotwald T. Radiographic anatomy of the sinuses. In: Kennedy DW, Bolger WE, Zinreich SJ, eds. Disease of the Sinuses: Diagnosis and Management. Lewiston, Newyork: B.C. Decker Inc, 2001:13-27.
4. Som PM, Shugar JMA, Brandwein MS. Anatomy and physiology, sinonasal cavities. In: Som PM, Curtin HD, eds. Head and Heck Imaging. St. Louis: Mosby, 2003:87-148.
5. Grass GW, McGeady SJ, Kerot T, et al. Limited CT in the evaluation of paranasal sinus disease in children. Am J Rhinol 1991;156:367-9.
6. Goodman GM, Martin DS, Klein J, Awwad E, Sharafuddin M. Comparison of a screening coronal CT versus a contiguous coronal CT for the evaluation of patient with presentative sinusitis. Ann Allergy Asthma Immunol 1995;74:172-82.
7. Keros P. On the practical value of differences in the level of the lamina cribosa of the ethmoid. J Laryngol Rhinol Otol 1962;41:809-13.
8. Bhattacharyya N, Fried MP. The accuracy of computed tomography in the diagnosis of chronic rhinosinusitis. Larygoscope 2003;113:125-9.
9. Zinreich SJ, Kennedy DW, Rosenbaum SE, et al. Paranasal sinuses: CT imaging requirement for endoscopic surgery. Radiology 1987;163:763-75.
10. Chow JM, Mcfee MF. Radiologic assessment preoperative to endoscopic sinus surgery. Otolaryngol Clin North Am 1989;22:691-701.
11. Calhoun KH, Waggenspack GA, Simpson B, Hokanson JA, Bailey BJ. CT evaluation of the paranasal sinuses in symptomatic and asymptomatic populations. Otolaryngol Head Neck Surg 1991;104:480-3.
12. Mafee MF. Modern imaging of paranasal sinuses and the role of limited sinus computerized tomography: Considering of time, cost and radiation. Ear Nose Throat J 1994;73:532-42.
13. Zinreich SJ, Albayram S, Benson ML, Oliverio PJ. The ostiomeatal complex and functional endoscopic surgery, sinonasal cavities. In: Som PM, Curtin HD, eds. Head and Heck Imaging. St. Louis: Mosby, 2003:149-74.
14. McNitt-Gray MF. Radiation dose in CT. Radiographics 2002;22:1541-53.
15. Duvoisin B, Landry M, Chapuis L, Krayenbuhl M, Schnyder P. Low-dose CT and inflammatory disease of the paranasal sinues. Neuroradiology 1991;33:403-6.
16. Franzese CB, Stringer SP. Economic analysis of the use of Limited Coronal Computed Tomography scans in the management of sinusitis. Am J Rhinol 2004;18:324-34.
17. Bolger WE, Butzin CA, Parson DS. Paranasal sinus bony anatomic variations and mucosal abnormalities: CT analysis for endoscopic sinus surgery. Laryngoscope 1991;101(1 Pt 1):56-64.
18. Nittinavakarn B, Thanaviratananich S, Sangsilp N. Anatomic variations of the lateral nasal wall and paranasal sinuses: A CT study for endoscopic sinus surgery (ESS) in Thai patients. J Med Assoc Thai 2005;88:763-8.