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APPLICATION OF CT IN DIAGNOSING CARCINOMA OF THE MAXILLARY SINUSES

PART 1: CLINICAL EVALUATION OF CT AND FRONTAL TOMOGRAPHY IN DIAGNOSING CARCINOMA OF THE MAXILLARY SINUSES

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ABSTRACT

Computed and frontal tomograms were taken of 20 patients with carcinoma of the maxillary sinus and were evaluated in order to compare the diagnostic accuracy of both procedures. Tomographic accuracy, sensitivity, and specificity in diagnosing tumor densities and bone defects were evaluated by comparing the tomogram's findings with the surgical results. The diagnostic accuracy of CT in diagnosing tumor densities was greater than that of frontal tomography. The value of both CT and frontal tomography in diagnosing bone defects was encouraging, but not conclusive. The future contributions of macrotomography and digital radiography in diagnosing carcinoma of the maxillary sinuses are the subjects of discussion in this paper.

Key words: CT, frontal tomography, maxillary sinus carcinoma, diagnostic accuracy

INTRODUCTION

Radiographic diagnosis of carcinoma of the maxillary sinuses employs several types of modalities.[1)-11)] The following examples are some of the procedures that are in current use:

a. Pluridirectional tomography.[9)] This procedure provides less redundunt shadows and better sharpness than conventional tomography.
b. Macrotomography [10)] makes it possible to image fine bony structure changes.
c. Axial transverse tomography[11)] visualizes the extent of a tumor in a transverse plane.

Computed tomography (CT) was introduced by Hounsfield *et al.*[12,13)] in 1972 and is frequently used in radiographic examinations of the nasal and paranasal sinuses. It is now a routine examination for carcinoma of the maxillary sinuses.

Visualization of tumor densities, bone destruction, and bone defects in order to determine the extent of carcinoma of the maxillary sinuses is the primary objective of radiographic diagnosis. Although the comparison of CT findings with the surgeon's results is necessary for the improvement of diagnostic accuracy, it is rarely done. In this paper I make these comparions, report my conclusinos, and discuss the future of radiographic diagnosis of carcinoma of the maxillary sinuses.

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MATERIALS AND METHODS

Histologically confirmed carcinomas of the maxillary sinuses of 38 patients, who were also examined by CT and frontal tomography at Nagoya University Hospital from March, 1978 to December, 1980, were studied. Twenty of these patients required total maxillectomies. Of these 20 patients, 17 suffered from squamous cell carcinoma, 2 from transitional cell carcinoma, and 1 from undifferentiated carcinoma (Table 1). Their ages ranged from 38 to 68 years old; 12 of whom were male, and 8 of whom were female.

Frontally tomographed 1–8 cm slices vertical to the orbito-meatal (OM) line using hypocycloidal motion ($2\theta = 40°$) with a pluridirectional tomography unit (Toshiba LGM-I) were performed at 0.5 and/or 1 cm intervals with the patients lying in a supine position. Exposures were made for 6 seconds at 60 kV and 50 mA with a Kyokko LT-II screen with Fuji RX film.

Fifteen CT examinations were performed with a 60 second EMI 1010 head scanner at 120 kV, and five CT examinations were performed with a 4 second Delta 2020 whole body scanner at 120 kV. Parallel sections were obtained along the OM line extending from the lower end of the maxillary sinus to the base of the skull using a 10 mm collimator.

Five radiologists individually interpreted the CT and frontal tomograms and were not informed of the clinical and surgical findings. They interpreted tumor densities of the paranasal sinuses, the nasal cavities, the orbits, the infratemporal fossas, the subcutaneous tissues of the cheek, and the bone defects of the walls of the maxillary sinuses and orbits. The criteria used for interpretation were "positive", "negative", and "not evaluable".

Total maxillectomy was performed after conducting CT and frontal tomography, surgical exploration, and ^{60}Co irradiation (5000-6000 rad (50-60 Gy)). Each radiologist's results were compared with the CT and frontal tomogram evaluations and with the findings of the total maxillectomies in order to determine the sensitivity (true positive rate), specificity (true negative rate), and accuracy of the CT and frontal tomograms.

I assumed that the combination of CT and frontal tomography was positive if at least one of them were positive, and determined the sensitivity, specificity, and accuracy by combining the CT and frontal tomograms evaluations of the 5 radiologists.

The comparison of CT and frontal tomography, and the comparison of a combination of CT and frontal tomography with CT alone were assessed by chi-square analysis. This same analytical procedure was done for the comparison of the combination of CT and frontal tomography with frontal tomography.

RESULTS

I evaluated the diagnostic accuracy of CT, frontal tomography, and the combination of both by first interpreting tumor densities (Table 2). The sensitivity and the accuracy of both CT and frontal tomography when applied to the maxillary sinuses and nasal cavities are great. The sensitivity of frontal tomography is significantly greater than that of CT, but the specificity of CT is significantly greater than that of frontal tomography when applied to the ethmoid sinuses. The sensitivity, specificity, and accuracy of CT are significantly greater than those of frontal tomography of the subcutaneous tissues of the cheek and the infratemporal fossas. The sensitivity and accuracy of CT are significantly greater than those of frontal tomography of the orbits. The specificity of CT is significantly greater than that of frontal tomography of the sphenoid sinuses and frontal sinuses. The diagnostic accuracy of the

combination of CT and frontal tomography is not siginificantly greater than that of CT or frontal tomography individually.

I then evaluated the diagnostic accuracy of bone defects (Table 3). The sensitivity and accuracy of both CT and frontal tomography of the medial walls of the maxillary sinuses are great. The sensitivity, specificity, and accuracy of CT are significantly greater than those of frontal tomography of the anterior walls of the maxillary sinuses. The sensitivity of CT (78 ± 21%) is significantly greater than that of frontal tomography (55 ± 26%), but the specificity of CT (37 ± 27%) is less than that of frontal tomography (63 ± 22%) of the posterior-lateral walls of the maxillary sinuses. The accuracy of CT (66 ± 6%) is almost the same as that of frontal tomography (70 ± 10%), but the combination of CT and frontal tomography (83 ± 7%) is significantly greater than that of either CT or frontal tomography of the inferior walls of the maxillary sinuses. The specificity and accuracy of CT are significantly greater than frontal tomography of the inferior walls of the orbits.

CASE REPORTS

I present 2 cases out of 4 that were erroneously diagnosed as being positive for bone defects of the posterior-lateral walls (PLW) of the maxillary sinuses by CT examination. These 4 patients were part of a group of 16 patients who were diagnosed for bone defects of the (PLW) by 5 radioligists. The 4 patients mentioned above were found to be free of the (PLW) bone defects when total maxillectomy was performed.

Case 7: A 50-year-old woman suffering from squamous cell carcinoma of the right maxillary sinus showed bone defects of the posterior-lateral wall of the right maxillary sinus by CT. Total maxillectomy performed after ^{60}Co irradiation (6000 rad (60 Gy)) revealed no bone defects of that wall (Fig. 1).

Case 9: A 47-year-old woman suffering from squamous cell carcinoma of the left maxillary sinus was initially diagnosed by CT as having bone defects of the posterior-lateral wall of the left maxillary sinus and tumor infiltration into the infratemporal fossa (Fig. 2A). A second CT series done 10 days before the operation and after ^{60}Co irradiation (6000 rad (60 Gy)) showed greater bone defectrs of that wall than did the initial CT (Fig. 2B). Total maxillectomy, however, revealed no bone defects.

Thus, even though CT may lead us to make erroneous diagnosis, it does detect many abnormalities not visualized by frontal tomography. The CT diagnoses for the 3 patients who had tumors of the infratemporal fossas, the 3 out of 5 patients who had tumors of the orbits, and the 5 out of 12 patients who had bone defects of the posterior-lateral walls of the maxillary sinuses were "truly positive", but the radiologists' interpretation of the frontal tomograms for the same were "erroneously negative". Therefore CT detected abnormalities in 9 out or 20 patients that were not detected by frontal tomography.

DISCUSSION

Visualization of tumor densities of the maxillary sinuses and bone destruction of the walls of the maxillary sinuses is the primary objective of radiographic diagnosis.[1)-4)] Tumor densities of the maxillary sinuses are not specific, but bone destruction or defects of the walls of the maxillary sinuses are always found in patients who are clinically suspected to have carcinoma of the maxillary sinuses.[2)] "Aggressive bone destruction" is characteristic in patients suffering from squamous cell carcinoma, but "bone expansion" may be shown in

patients suffering from slow-growing diseases such as: carcinomas other than squamous cell carinoma, malignant tumors other than carcinoma, benign tumors, and inflammatory diseases.[5,8] Visualization of bone changes of the maxillary sinuses is important in distinguishing malignant diseases from benign ones.

Hamasaki reported that tomographical visualization of bone defects of the lateral, anterior, inferior, and posterior walls of the maxillary sinuses was possible by plain roentogenograms, but that visualization of bone defects of the medial walls of the maxillary sinuses and the inferior walls of the orbits was only possible by frontal tomograms.[2] Dodd's systematic use of tomograms in diagnosing carcinoma of the paranasal sinuses stressed that minimal bone destruction, which is frequently masked in plain roentogenograms by surrounding or superimposed intact bone, was easily detected by tomograms.[1] Aihara reported that destruction of the posterior walls of the maxillary sinuses and the pterygoid processes was better visulaized by means of horizontal tomograms than by axial views.[3] Matsuda reported that bone destruction of the medial, lateral, superior, and inferior walls of the maxillary sinuses was better visualized by axial transverse tomograms than by frontal tomograms.[11]

Tomograms, especially frontal tomograms, have very wide use, but CT is now being more broadly used in the assessment of suspected carcinoma of the maxillary sinuses, thereby requiring us to study the merits and demerits of both CT and frontal tomography. Tomograms of the coronal plane and the axial plane in diagnosing carcinoma of the maxillary sinuses are required in determining the extent of tumor infiltration and bone involvement. The procedures used to obtain tomograms of the transverse plane are CT, axial tomography and axial transverse tomography. Axial tomography has a patient positioning problem and much lower contrast than CT; axial transverse tomography has only the problem of low contrast. Tomograms in a coronal plane can be obtained by coronal CT and coronal reconstruction of axial CT as well as by frontal tomography. Coronal CT[14] can visualize soft tissue density not visualized in frontal tomograms. Coronal CT, however, has the following problems: (1) less spatial resolution than frontal tomograms, (2) artifacts caused by artificial dentures, (3) difficulty in routine use due to crowded CT examination schedules. Coronal reconstruction of axial CT, although its image quality has been greatly improved, still has less spatial resolution than direct coronal CT. My studies concentrated on the comparison of the diagnostic accuracy of frontal tomograms with axial CT and took into accout the different aspects of the detection of bone defects. One such aspcet is the ability of both CT and frontal tomograms to clearly visualize the medial wall of the maxillary sinuses. Another consideration is the imaging of the inferior wall of the maxillary sinuses; here it is better to use both CT and frontal tomograms because their combined accuracy is greater than individual CT or frontal tomograms. Still another aspect is the visualization of the inferior wall of the orbits, for which the diagnostic accuracy of CT is less than that of frontal tomograms because the thin inferior wall of the orbit lies in the same plane as the scan, making imaging extremely difficult;[15] coronal plane CT, however, will improve the diagnostic accuracy of CT. Another aspcet to be considered is the visualization of the anterior and posterior-lateral walls of the maxillary sinuses. Here the diagnostic accuracy of CT is greater than that of frontal tomography because CT can be used specifically for transverse plane tomography. Some cases were erroneously diagnosed as being positive for bone defects of the posterior-lateral walls of the maxillary sinuses by CT examinations. The reasons for these mistakes are as follows: (1) the difference of the time between CT examination and surgery may result in regeneration of the bony wall corresponding with the tumor's regression as a result of radiation therapy; (2) problems with image processing such as undershooting;[16]

and (3) partial volume phenomenon.[16] Another problem of CT in diagnosing bony changes is that bony walls surrounding the maxillary sinuses are inclined to be visualized thicker in CT images than in vivo. Progress in solving the problems presented above will be reported in a later paper.

Conventional methods do not lend themselves to distinguishing malignant tumors from benign diseases, nor do they image tumor extension to the infratemporal fossas, the orbits, or the intracranial regions. The good contrast resolution of CT is expected to facilitate the differentiation of malignant tumors from benign diseases. Parsons,[15] however, reported that measurement of tissue densities was not helpful in distinguishing tumors from benign diseases. Reports on contrast enhancement of maxillary sinus malignancies are unfavorable due to cancer's avascular nature.[15,17)-21)] It appears that the cancerous tissue and the normal surrounding tissues are equally enhanced, thereby rendering the entire procedure ineffective for distinguishing the malignant tumor from the benign disease or evaluating the extent of the tumor.

Accuracy in detecting tumor density by CT is the same as or greater than that of frontal tomography of all regions. This is especially significant in the subcutaneous tissues of the cheek, the infratemporal fossas, and the orbits, where conventional tomograms cannot visualize the tumor's density. The bone defects of the posterior-lateral walls of the maxillary sinuses and the tumor density of the orbits and the infratemporal fossas, which were not detected by frontal tomograms, inspection, and/or palpation, were detecterd by CT. This was clearly demonstrated in 9 out of the 20 previously mentioned patients whose methods of radiation therapy were changed.

The resolving power of our pluridirectional tomography unit is 2.2–2.4 lp/mm, and the high contrast resolving power of our CT (EMI-1010) is 0.25–0.29 lp/mm.[16] The resolving power of pluridirectional tomography units recently developed, however, is 4–5.55 lp/mm in conventional tomography, and 5.55–9.63 lp/mm in three-fold magnification tomography.[10] The high contrast resolving power of target imaging of CT units recently developed is 0.67–1.00 lp/mm.

Frontal tomography can be used in diagnosing bone defects of the inferior walls of the orbits and the inferior walls of the maxillary sinuses. Greater use of macrotomography for visualization of subtle bone defects of the inferior and medial walls of the orbits and for distinguishing malignant tumors from benign diseases by detection of subtle bone defects of the septums of the ethmoid cells is expected in the near future. Application of digital radiography to tomography will improve its image quality making axial transverse tomography and axial tomography, which are not in frequent use, routine procedures in the detection of fine bone defects, presently not detectable in CT, of the anterior and posterior-lateral walls of the maxillary sinuses, the medial walls of the orbits, and the septums of the ethmoid cells.

CONCLUSION

I compared the diagnostic accuracy of CT and frontal tomograms in the diagnosis of carcinoma of the maxillary sinuses by comparing radiographic and surgical results.

Diagnostic accuracy of CT in regard to tumor density was generally greater than that of frontal tomography. The merits or using CT or frontal tomography for diagnosing bone defects are still inconclusive. I therefore feel that CT and frontal tomograms are complimentary. I also conclude that macro-tomography and digital radiography can improve the image quality of radiography and its diagnostic accuracy.

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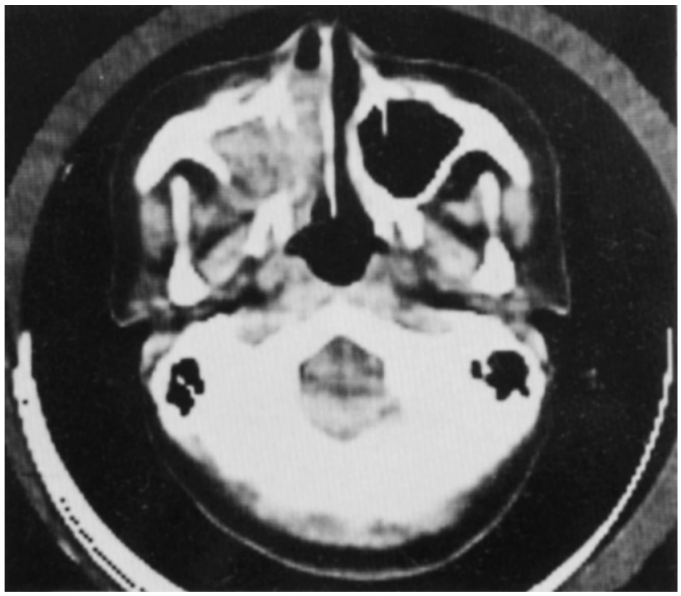

Fig. 1 CT of Case 7 showing bone defects of the posterior-lateral wall of the right maxillary sinus. Total maxillectomy performed after ^{60}Co irradiation (6000 rad (60 Gy)) revealed no bone defects of that wall.

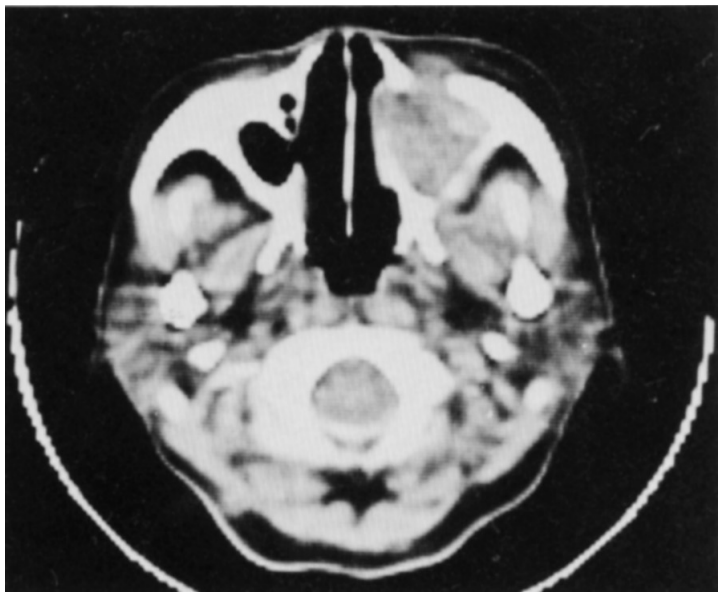

Fig. 2A The initial CT of Case 9 showing bone defects of the posterior-lateral wall of the left maxillary sinus and tumor infiltration into the infratemporal fossa.

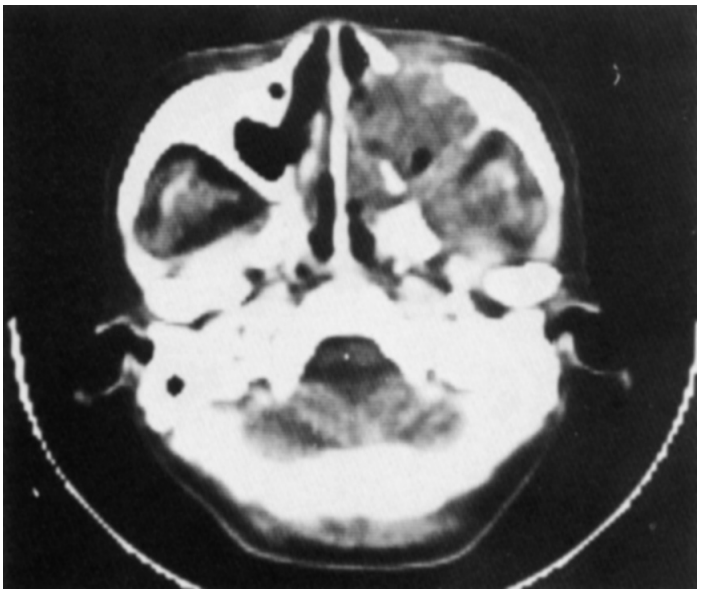

Fig. 2B The second CT of Case 9, 10 days before the operation, after ^{60}Co irradiation (6000 rad (60 Gy)) showing greater bone defects of the posterior-lateral wall than the initial CT (Fig. 2A). Total maxillectomy revealed no bone defects of that wall.

Table 1. Cases of carcinoma of the maxillary sinus

No.	Name	Age	Sex	laterality	
1.	Y. S.	49	M	L	squamous cell carcinoma
2.	M. H.	53	M	L	〃
3.	K. Y.	62	M	R	〃
4.	M. S.	65	F	L	transitional cell carcinoma
5.	T. S.	41	M	L	squamous cell carcinoma
6.	K. K.	60	F	L	〃
7.	Y. S.	50	F	R	〃
8.	Y. N.	55	M	R	carcinoma (unclassified)
9.	I. Y.	47	F	L	squamous cell carcinoma
10.	M. Y.	65	M	R	〃
11.	T. S.	57	M	L	〃
12.	I. S.	64	F	R	〃
13.	K. M.	38	M	L	〃
14.	K. K.	38	F	R	transitional cell carcinoma
15.	H. K.	51	M	R	squamous cell carcinoma
16.	M. N.	55	M	L	〃
17.	T. M.	41	M	L	〃
18.	H. S.	50	F	L	〃
19.	Y. H.	53	M	R	〃
20.	Y. A.	68	F	L	〃
Total		38—68	12/8 M F	12/8 L R	s.c.c.: 17, t.c.c.: 2 ca (unclassified) :1

Table 2. Sensitivity, Specificity, and accuracy in detecting tumor density

Site	Modality	Sensitivity (%)		Specificity (%)		Accuracy (%)	
		N.	Mean ± S.D.	N.	Mean ± S.D.	N.	Mean ± S.D.
Maxillary Sinus	CT	20	100 ± 0	0	–	20	100 ± 0
	Tomo		100 ± 0		–		100 ± 0
	CT + Tomo		100 ± 0		–		100 ± 0
Nasal Cavity	CT	14	99 ± 3	3	33 ± 24	17	87 ± 3
	Tomo		96 ± 6		13 ± 18		81 ± 3
	CT + Tomo		100 ± 0		13 ± 18		95 ± 6
Ethmoid Sinus	CT	11	69 ± 15	5	60 ± 25*	16	66 ± 10
	Tomo		89 ± 10*		28 ± 11		70 ± 5
	CT + Tomo		93 ± 8		28 ± 11		73 ± 6
Cheek	CT	7	63 ± 8 ***	6	90 ± 15***	13	75 ± 3***
	Tomo		0		3 ± 8		2 ± 3
	CT + Tomo		63 ± 8		90 ± 15		75 ± 3
Infratemporal Fossa	CT	3	93 ± 15***	9	60 ± 27*	12	68 ± 19
	Tomo		13 ± 18		33 ± 34		28 ± 25
	CT + Tomo		93 ± 15		51 ± 26		62 ± 19
Orbit	CT	5	76 ± 26*	7	60 ± 12	12	67 ± 6*
	Tomo		44 ± 38		40 ± 44		42 ± 35
	CT + Tomo		96 ± 9		51 ± 16		70 ± 7
Sphenoid Sinus	CT	1	0	10	80 ± 12***	11	73 ± 11***
	Tomo		0		50 ± 14		45 ± 13
	CT + Tomo		0		66 ± 17		60 ± 15
Frontal Sinus	CT	0	–	4	80 ± 11***	4	80 ± 11***
	Tomo		–		30 ± 27		30 ± 27
	CT + Tomo		–		65 ± 38		65 ± 38

* $P < 0.05$

** $P < 0.01$

*** $P < 0.005$

Tomo: frontal tomography

Table 3. Sensitivity, Specificity, and accuracy in detecting bone defects

Site	Modality	Sensitivity (%)		Specificity (%)		Accuracy (%)	
		N.	Mean ± S.D.	N.	Mean ± S.D.	N.	Mean ± S.D.
Medial Wall	CT	18	92 ± 12	1	0	19	87 ± 12
	Tomo		97 ± 5		0		92 ± 5
	CT + Tomo		98 ± 5		0		93 ± 5
Anterior Wall	CT	9	69 ± 15***	7	89 ± 12***	16	78 ± 7***
	Tomo		9 ± 20		6 ± 13		8 ± 17
	CT + Tomo		73 ± 17		86 ± 10		79 ± 8
Posterior-lateral Wall	CT	13	78 ± 21**	6	37 ± 27	19	65 ± 11
	Tomo		55 ± 26		63 ± 22		58 ± 19
	CT + Tomo		88 ± 12		30 ± 25		69 ± 8
Inferior Wall	CT	10	70 ± 10	9	62 ± 17	19	66 ± 6
	Tomo		60 ± 16		80 ± 15		70 ± 10
	CT + Tomo		86 ± 11		80 ± 16		83 ± 7*
Inferior Wall	CT	9	47 ± 21	11	27 ± 28	20	36 ± 20
	Tomo		67 ± 11		60 ± 32***		63 ± 14***
	CT + Tomo		78 ± 8		51 ± 24		63 ± 12
Medial Wall	CT	3	60 ± 15	1	100 ± 0	4	70 ± 11
	Tomo		33 ± 41		80 ± 45		45 ± 21
	CT + Tomo		78 ± 8		80 ± 45		75 ± 0

* $P < 0.05$

** $P < 0.01$

*** $P < 0.005$

Tomo: frontal tomography