原　著

Classification of Sphenoid Sinus Using Head Computed Tomography Images for Preliminary of Personal Identification.

Appu Gammahelage Chandani Malkanthi[1,2], Naoya TAKAHASHI[1,3,4], Tomoya FUSE[1]
Amon OHSAWA[1], Hisakazu TAKATSUKA[4], Takeshi HIGUCHI[3]

Key words：Sphenoid sinus, Computed tomography, Identification, Disaster victims

Abstract Objectives: The purpose of this study was to develop a simple and accurate method of classification of the sphenoid sinus using head computed tomography (CT) for disaster victim identification.
Materials and methods: Antemortem and postmortem CT (AMCT, PMCT) images of 112 cases were examined by two examiners (A and B). The sphenoid sinus was classified into seven patterns based on two parameters; number of protrusions and the position of the complete septum. The rates of each pattern, the intra-examiner coincidence rate between AMCT and PMCT, and the inter-examiner coincidence rate for AMCT and PMCT were evaluated.
Results: It was difficult to evaluate in one case with effusion in the sphenoid sinus on PMCT. We evaluated 112 AMCT and 111 PMCT. The percentage for number of protrusion(s) 1: 25.9%, 2: 51.8% (right side dominant complete septum 18.8%, left side dominant complete septum 33.0%), 3: 20.6% (right side dominant complete septum: 1.79%, left side dominant complete septum: 17.0%, center dominant complete septum: 1.79%), 4 or more: 1.79% on AMCT. Intra-examiner coincidence rates between AMCT and PMCT were 89.2% and 95.5% for examiner A and B, respectively. Inter-examiner coincidence rates between examiners were 97.3% and 98.2% for AMCT and PMCT, respectively.
Conclusion: The sphenoid sinus classification method developed in this study was a useful tool that could be utilized easily and effectively for preliminary of personal identification regardless of examiners in the cases of mass disasters.

1. INTRODUCTION

In recent years post-mortem imaging (PMI) using modern digital technologies, e.g. multi-detector CT (MDCT) or magnetic resonance imaging, has introduced to forensic fields[1-4]. Radiologists should have forensic knowledge to deal with PMI[5]. Confirmation of the identity of an unknown person is a crucial task in forensic medicine[6-9]. Personal identification by utilizing matching ante-mortem and post-mortem radiographs has been common to date. Skeletal parts which show anatomical variations or which are resistant to changes due to trauma or illness are more reliable sources that can be used in personal identification[10]. The paranasal sinus is one of the most suitable parts for personal identification. Frontal sinus has generally been used on skull radiographs[11-15]. A significant shift in radiological assessment of the head from skull radiographs to head CT is caused due to limited clinical utility of skull radiographs and widespread availability of computed tomography[16]. Some investigators have studied frontal sinus morphology on CT for personal identification[17-19]. However, to our knowledge, there have been few studies regarding the sphenoid sinus in determining personal identification[6;20]. The sphenoid sinuses have great variability among individuals and their structures do not

1) School of Health Sciences, Faculty of Medicine, Niigata University
2) Faculty of Allied Health Sciences, University of Peradeniya, Sri Lanka
3) Department of Radiological Diagnosis, Niigata City General Hospital
4) Center for Cause of Death Investigation, Niigata University
Accepted：2019.11.8

Table 1: Acquisition protocol for head of each CT scanner

CT scanner	Number of detectors	Tube voltage (kV)	Tube current (mA)
Sensation 16	16	120	320
Emotion 6	6	130	186-240
Definition AS	64	120	275
Sensation 64	64	120	250

change after adulthood[21; 22]. They are divided into two compartments separated by a septum which may or may not be in the middle. A large sinus can show a number of ridges and depressions related to closely adjacent structures. The post-mortem imaging has been recommended in mass disasters. It is important that the large number of victims are divided into some groups in mass disasters for preliminary of personal identification.

In this study, we focused on the position of the septum and the number of protrusions of the sphenoid sinus which are shown in an axial CT image of the head. The uniqueness of these features of the sphenoid sinus can be used for the purpose of personal identification. The aim of this study was to develop a reliable and accurate classification method of the sphenoid sinus for preliminary of personal identification.

2. MATERIALS AND METHODS

2.1 Obtaining of CT data.

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This retrospective study was approved, and informed consent was not required by the review board of Niigata City General Hospital (16-003). One hundred fourteen postmortem case data were collected from the Niigata City General Hospital, which were performed between 21st December 2008 and 21st March 2012. Antemortem head CT (AMHCT) data corresponding to postmortem head CT (PMHCT) data were also collected. All cases we had collected were Japanese. Among 114 PMHCT data, 2 cases were excluded. One patient was suffering from an olfactory nerve tumor and the sphenoid sinus was destroyed due to the tumor. Another patient, who was not an adult, did not have a developed sphenoid sinus. Therefore, 112 cases were subjected to the study.

2.2 CT examinations

We used two 64-row MDCT units (SOMATOM Definition AS and SOMATOM Sensation 64, Siemens Healthineers, Erlangen, Germany), a 16-row detector MDCT unit (SOMATOM Sensation 16, Siemens Healthineers, Erlangen, Germany), and a 6-row detector MDCT unit (SOMATOM Emotion 6, Siemens Healthineers, Erlangen, Germany) for antemortem CT. SOMATOM Definition AS, SOMATOM Sensation 16, and SOMATOM Sensation 64 were used to perform PMHCT. Both antemortem and postmortem examinations were performed in the natural supine position within the following parameters recommended by the manufacturer (Table 1). Images for the head were obtained of a 5 mm slice thickness with a 200 mm field of view and a 512 x 512 imaging matrix using the sequence mode from the level of the foramen magnum to the skull vertex.

2.3 Evaluation of CT images

Evaluation of CT images was performed by two medical students. These students received instruction from a supervisor (an experienced board-certified radiologist) about the anatomical structure of paranasal sinuses on CT before evaluation. Digital imaging and communication in medicine (DICOM) data of CT were evaluated on personal computers. A DICOM viewer (RadiAnt 4.3.0, Medixant, Poznan, Poland) was used to observe head CT images and to make multi-planar reconstruction (MPR) images. MPR images were reconstructed correctly as the axial plane parallel to orbitomeatal lines according to the method proposed by Ruder et al[23]. The supervisor guided the students how to make MPR images. The examiners made MPR images, and evaluated the images, independently. In order to observe bone structure and air in the paranasal sinuses, window level (WL) and window width (WW) were set as 1000 Hounsfield Units (HU) and 4000 HU, respectively, according to the study by Ruder et al[23].

Every sphenoid sinus had one or some protrusions. One of these protrusions which divided the sphenoid sinus was defined as a complete septum. We set two simple parameters using the number of the protrusions and the position of the complete septum (Figure 1).

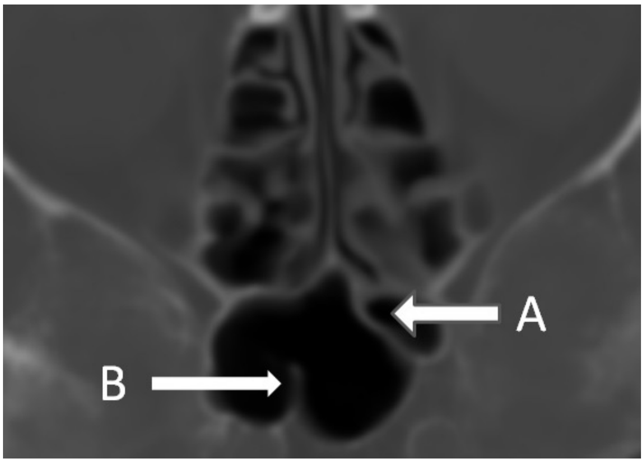

Figure 1: Multi-planar reconstruction image at the sphenoid sinus in a case with two protrusions including the complete septum on the left side. Parameters used to the sphenoid sinus classification. A: Complete septum, B: Protrusion.

Parameter 1: Number of protrusions in the sphenoid sinus as 1, 2, 3, and 4 or more.
Parameter 2: Position of the complete septum as right, center or left.

Sphenoid sinuses were classified into seven patterns (Table 2) (Figure 2) by means of these parameters.

Two examiners (A and B) independently evaluated 112 AMHCT and PMHCT. If the examiner was uncertain about an exact pattern, she or he had the chance to select two or more patterns for a sphenoid sinus.

We evaluated the intra-examiner coincidence rate by comparing the case on AMHCT with the same case on PMHCT for examiner A and examiner B, and also evaluated the inter-examiner coincidence rate between examiner A and examiner B one case by one case for AMHCT and PMHCT. For the cases which two examiners selected two or more patterns, we decided them agreement when at least one pattern accorded.

Following the evaluation of the coincidence rates, we calculated the rate of each pattern using AMHCT. When the classifications decided by two examiners were different, the final classification was reached in consensus by two examiners and the supervisor.

3. RESULTS

When examining the pattern of the sphenoid sinus on PMHCT, one case was found with effusion. It was difficult to evaluate the pattern in this case. Therefore, a total number of 111 postmortem cases were evaluated.

The intra-examiner coincidence rate between AMHCT and PMHCT was 89.2% (99/111) for examiner A and 95.5% (106/111) for examiner B. The inter-examiner coincidence rate was 97.3% (109/112) for AMHCT and 98.2% (109/111) for PMHCT.

The percentage of each pattern of the sphenoid sinus

Table 2: Sphenoid sinus classification.

Pattern	Number of protrusion(s)	Position of the complete septum
a	1	-
b	2	Right
c	2	Left
d	3	Right
e	3	Center
f	3	Left
g	4 or more	-

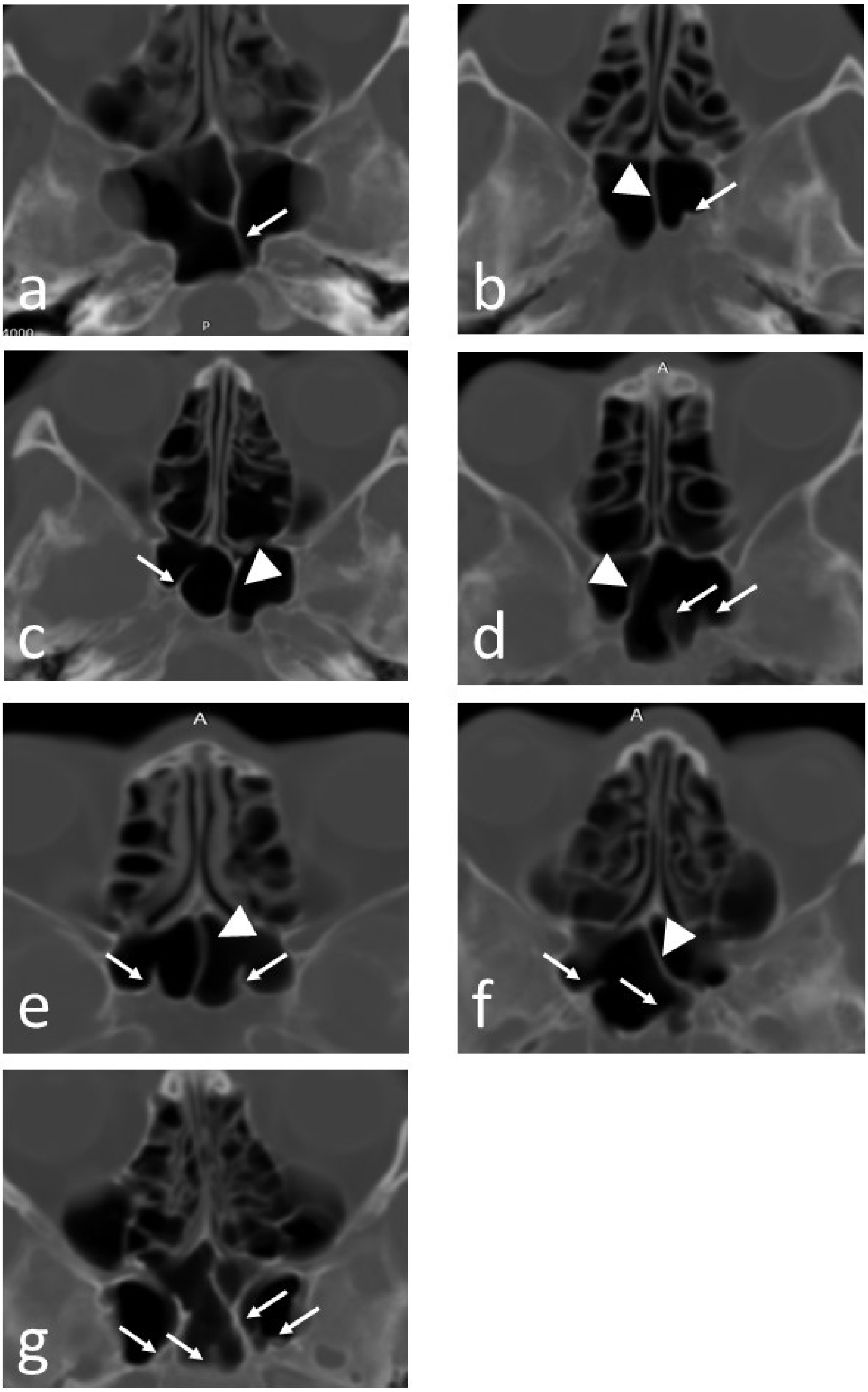

Figure 2: Multi-planar reconstruction image at the sphenoid sinus. Seven patterns of the sphenoid sinus. (a); 1 protrusion, (b); 2 protrusions including the complete septum on the right side, (c); 2 protrusions including the complete septum in the left side, (d); 3 protrusions including the complete septum in the right side, (e); 3 protrusions including the complete septum in the center, (f); 3 protrusions inclusing the complete septum in the left side, (g); 4 protrusions. Arrows: protusions, arrowheads: septa.

recorded was calculated using AMHCT data (Figure 3). According to those percentages the majority of the cases have 2 protrusions in their sphenoid sinus and a fewer number of cases have 3 protrusions or more.

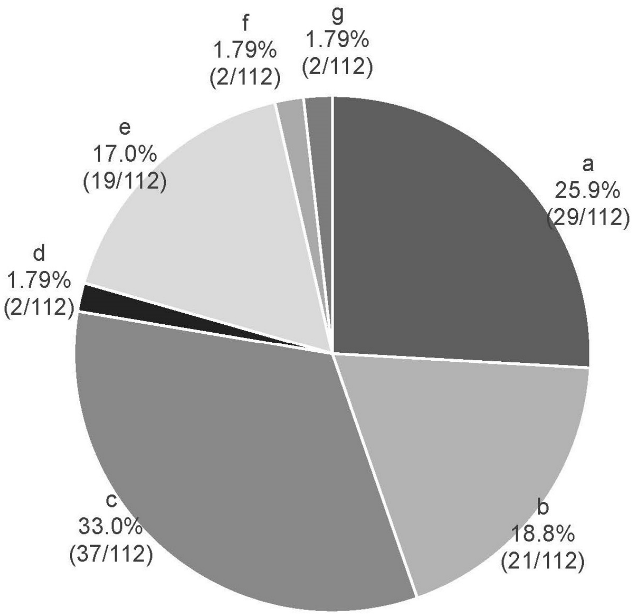

Figure 3: Number and percentage for each pattern.

4. DISCUSSION

Methods of personal identification by using the shape of the sinus as shown in skull radiographs were published in past studies[11-15; 24; 25]. Some investigators have proposed methods of personal identification using head CT in a mass disaster[6; 8]. The number of CT scanning installations and usage of CT scanning were increased on these days. Head CT is done most often on approximate 40% of all CT examinations[26] because of its many indications[16]. The number of CT examinations in Japan is 230.8 per 1000 population in 2015[27]. Approximately 100 head CT examinations per 1000 population were performed per year in Japan. There is a high possibility for a disaster victim to have undergone a head CT scan in his or her life time. Head CT examination is usually performed with a 5 mm slice thickness with a 200 mm field of view and a 512 x 512 imaging matrix using the sequence mode. Hence we used common head CT parameter in our study.

In mass disasters there are large number of victims. It needs a great deal of time and labor to compare a lot of CT images one by one. Hence, classification of data is important. The sphenoid sinus visible in head CT images has a unique shape that varies from person to person[21; 22] and can be used as evidence for personal identification[20; 23]. Though the sphenoid sinus was compared one by one on the antemortem and postmortem images in the previous studies[20; 23], there is no study about the classification of sphenoid sinus for preliminary of personal identification. In this present study, sphenoid sinuses were classified into seven patterns based on two simple parameters and respective percentages were calculated for each pattern. If the parameters were too complicated, there was a high risk of misidentification. Because of this reason the number of protrusions and the position of the complete septum were selected as parameters, and the number of patterns was set only to seven. This newly developed method did not require any process such as obtaining measurements and is a simple visual classification. This simple sphenoid sinus visual classification method can be used easily and effectively for personal identification in mass disasters.

Our study revealed that the majority of the cases exhibited 1 or 2 protrusions in the sphenoid sinus. The cases with 3 protrusions occurred about 20% of the time and cases with 4 protrusions or more about only 2% of the time. Sphenoid sinuses may be classified into four patterns: 1 protrusion (25.9%), 2 protrusions with right complete septum (18.8%), 2 protrusions with left complete septum (33.0%), and 3 protrusions or more (22.3%). Each pattern comprises approximately the same rate. Therefore, the classification will be easier and simpler.

Our study has several limitations. Firstly, the intra-examiner coincidence rates between AMHCT and PMHCT were a little lower. The images were evaluated by medical students with less experience in diagnostic imaging. Ruder et al reported that there was statistically significant difference between radiologists and non-radiologists in sensitivity of interpretation for identification using paranasal sinuses on AMHCT and PMHCT[6]. If a radiologist or a person who engaged in image diagnosis for a long time would perform the classification, the coincidence rates may be higher than in this study. Secondly, the most of the sphenoid sinuses were filled with air in this study. The thin septum or protrusion may be obscure when the sphenoid sinus was filled with matter, hence it may be difficult to evaluate the images. Particularly, drowning persons tend to have effusion in their paranasal sinus[28; 29]. It may be difficult to evaluate sphenoid sinus in water accidents.

5. CONCLUSION

We proposed a new classification of the sphenoid sinus into seven patterns on the head CT for preliminary of personal identification. This method was a useful tool that could be utilized easily and effectively for preliminary of personal identification regardless of the examiner in the case of mass disasters.

References

1) Flach PM, Thali MJ, Germerott T. Times Have Changed! Forensic Radiology－A New Challenge for Radiology and Forensic Pathology. Am J Roentgenol. 2014; 202:W325-W334
2) O'Donnell C, Rotman A, Collett S, N W. Current status of routine post-mortem CT in Melbourne, Australia. Forensic Sci Med Pathol. 2007;3:226-232
3) Okuda T, Shiotani S, Sakamoto N, et al. Background and current status of postmortem imaging in Japan: short history of "Autopsy imaging (Ai)". Forensic Sci Int. 2013;225:3-8
4) Roberts IS, Benamore RE, Benbow EW, et al. Post-mortem imaging as an alternative to autopsy in the diagnosis of adult deaths: a validation study. Lancet. 2012;379:136-142
5) O'Donnell C, Woodford N. Post-mortem radiology--a new sub-speciality? Clin Radiol. 2008;63:1189-1194
6) Ruder TD, Kraehenbuehl M, Gotsmy WF, et al. Radiologic identification of disaster victims: a simple and reliable method using CT of the paranasal sinuses. Eur J Radiol. 2012;81:e132-138
7) O'Donnell C, Iino M, Mansharan K, et al. Contribution of postmortem multidetector CT scanning to identification of the deceased in a mass disaster: Experience gained from the 2009 Victorian bushfires. Forensic Sci Int2011) 205:15-28
8) Gascho D, Philipp H, Flach PM, et al. Standardized medical image registration for radiological identification of decedents based on paranasal sinuses. J Forensic Leg Med. 2018;54:96-101
9) Shepherd R: Identification of the living and the dead. In: Simpson's Forensic Medicine. Hodder Arnold, 2003, London, p 49 - 55
10) Brogdon BG: Radiological identification of individual remains. In: Thali MJ, Viner MD, Brogdom BG, editors: Brogdon's Forensic Radiology. CRC Press, 2011 NW, p 153 -176
11) Buyuk SK, Karaman A, Yasa Y. Association between frontal sinus morphology and craniofacial parameters: A forensic view. J Forensic Leg Med. 2017;49:20-23
12) Nikam SS, Gadgil RM, Bhoosreddy AR, et al. Personal Identification in Forensic Science Using Uniqueness of Radiographic Image of Frontal Sinus. J Forensic Odontostomatol. 2015;33:1-7
13) Besana JL, Rogers TL. Personal identification using the frontal sinus. J Forensic Sci. 2010;55:584-589
14) da Silva RF, Prado FB, Caputo IG, et al. The forensic importance of frontal sinus radiographs. J Forensic Leg Med. 2009;16:18-23
15) Quatrehomme G, Fronty P, Sapanet M, et al. Identification by frontal sinus pattern in forensic anthropology. Forensic Sci Int. 1996;83:147-153
16) Tress BM The need for skull radiography in patients presenting for CT. Radiology. 1983;146:87-89
17) Tatlisumak E, Yilmaz Ovali G, Aslan A, et al. Identification of unknown bodies by using CT images of frontal sinus. Forensic Sci Int. 2007;166:42-48
18) Souza LA, Jr., Marana AN, Weber SAT. Automatic frontal sinus recognition in computed tomography images for person identification. Forensic Sci Int. 2018;286:252-264
19) Beaini TL, Duailibi-Neto EF, Chilvarquer I, et al. Human identification through frontal sinus 3D superimposition: Pilot study with Cone Beam Computer Tomography. J Forensic Leg Med. 2015;36:63-69
20) Auffret M, Garetier M, Diallo I, et al. Contribution of the computed tomography of the anatomical aspects of the sphenoid sinuses to forensic identification. J Neuroradiol. 2016;43:404-414
21) Becker SS, O'Malley BB Evaluation of sinus computed tomography scans: a collaborative approach between radiology and otolaryngology. Curr Opin Otolaryngol Head Neck Surg. 2013;21:69-73
22) Sirikci A, Bayazit YA, Bayram M, et al. Variations of sphenoid and related structures. Eur Radiol. 2000;10:844-848
23) Ruder TD, Brun C, Christensen AM, et al. Comparative radiologic identification with CT images of paranasal sinuses – Development of a standardized approach. J Forensic Radiol and Imaging. 2016;7:1-9
24) de Oliveira Musse J, Marques JAM, de Oliveira RN. Contribuição da análise do seio maxilar para a identificação humana. Saúde, Ética & Justiça. 2009;14:65-76
25) Xavier TA, Dias Terada ASS, da Silva RHA. Forensic application of the frontal and maxillary sinuses: A literature review. J Forensic Radiol and Imaging. 2015;3:105-110
26) Nishizawa K, Matsumoto M, Iwai K, et al. Survey of CT Practice in Japan and Collective Effective Dose Estimation. Nippon Acta Radiol. 2004;64:151-158
27) OECD (2017) Health at a Glance 2017. OECD Publishing, Paris. Available via https://www.google.com/search?client=firefox-b-d&q=health+at+a+glance+2017 Accessed Feburary 26th, 2019
28) Levy AD, Harcke HT, Getz JM et al Virtual autopsy: two- and three-dimensional multidetector CT findings in drowning with autopsy comparison. Radiology. 2007;243:862-868
29) Christe A, Aghayev E, Jackowski C, et al. Drowning--post-mortem imaging findings by computed tomography. Eur Radiol. 2008;18:283-290