Rhinology, 48, 11-17, 2010

Variations of the paranasal sinuses in Melanesians as observed by CT*

M. Robinson[1], D. Donlon[1], H. Harrison[2], M. Houang[3], H. Stammberger[4], G. Wolf[4]

1 Discipline of Anatomy and Histology and Bosch Institute, University of Sydney, Australia
2 Ear, Nose and Throat Departments, Sydney Hospital and Sydney Children's Hospital, Australia
3 Sydney CT & MR, Sydney, Australia
4 University ENT-Hospital, Graz, Austria

SUMMARY

Studies have reported the incidence of anatomical variants of the paranasal sinuses for specific populations with a view to helping surgeons avoid possible complications during functional endoscopic sinus surgery. Some have found significant variation when comparing different populations. The current study has used computed tomography (CT) scans to observe variations in the paranasal sinuses in a non-random sample of museum skulls of Melanesians, a racial group that has not previously been studied in this respect. The incidence of variants found were: agger nasi cells 59.5%, concha bullosa 41.5%, Haller's air cells 31.7%, internal carotid artery bulge in the sphenoid sinus 23.8%, supraorbital cells 16.7%, paradoxical curvature of the middle turbinate 7.5% and pneumatization of crista galli 7.1%.
Because of contradictory findings in the literature as to the incidence of such variations between racial groups the authors are able to make only limited meaningful comparisons between their subjects and other such groups.

Key words: paranasal sinuses, variation, Melanesian, CT, skulls

INTRODUCTION

In recent years there has been a steady increase in the number of studies published investigating the anatomical variations of the paranasal sinuses. This increase is probably due to the widespread use of CTs for diagnostic purposes and the improvement in resolution of these new machines, providing more accurate visualisation of complex human anatomy. There are many observable commonly occurring variants of the paranasal sinuses and nasal cavity, most being harmless, while others are of surgical importance if they obstruct normal operating procedures. Some variants may be linked to disease conditions and a few pose a risk to critical neurovascular structures during functional endoscopic sinus surgery.

It has been suggested (1-3) that very high incidences of certain variants in certain populations may be due to racial variation. There has been little work done to test this hypothesis. Badia and colleagues (2) found that there is a higher incidence of sphenoethmoid cells in Hong Kong Chinese compared to Caucasoids in the UK. Thanaviratananich and colleagues (3) examined studies of Onodi cell prevalence in a number of countries for comparison with Thai cadavers and found consistently higher incidences when the method of investigation was endoscopy rather than CT. Nevertheless, Thai cadavers still had a higher incidence in respect to populations from all other racial groups. In studies of the frontal sinus patterns, several authors (4-7) conclude that the differences between samples may be due to racial variation as well as other possible factors. Kawamura and colleagues (6) have even found differences between the frontal sinuses of Melanesians and Polynesians.

Several common anatomical variants are often implicated in chronic sinus disease. Of all the observable anatomic variations of the paranasal sinuses that are thought to be conducive to sinusitis few have actually been proven in studies comparing symptomatic and asymptomatic patients. Calhoun and colleagues (8) have found that only septal deviation and concha bullosa correlate significantly with patients who have sinus disease. Others believe most cases of concha bullosa are not responsible for sinusitis but there are reports of it obstructing the middle meatus thereby resulting in recurrent ethmoiditis (9). Conversely, other studies (10-13) concur that bony anatomical variations are not themselves the cause of sinus disease, rather that intrinsic mucosal abnormalities and mucosal contact are of greater importance.

The anatomical variants can be discribed in short as follows:
Agger nasi cells occur very frequently and could almost be considered to be a normal part of the anatomy rather than a variant. In cases where agger nasi cells form part of the drainage path for the frontal sinus, these cells may be responsible for recurrent or chronic inflammation of the frontal sinus (9).

*Received for publication: May 15, 2009; accepted: July 25, 2009

DOI:10.4193/Rhin09.083

Concha bullosa may reduce surgical access to the sinuses [14]. Similarly, paradoxical curvature of the middle concha is only thought to be problematic if it causes obstruction of the middle meatus and ethmoid infundibulum [14,15].
Haller's cells have been thought to be a cause of recurrent inflammation of the maxillary sinus; this is however not supported by some studies [9,16].
Of the variants that may place important neurovascular structures at risk during surgery, bulging of the carotid artery due to excessive pneumatization of the sphenoid sinus and optic nerve protrusion in posterior ethmoid cells (Onodi cells) are the two most prominent. The thin lamina of bone over the internal carotid artery may be accidentally breached during exploration of the sphenoid sinus [18-21]. A patient may be at risk of blindness or death if the surgeon is not aware of their vulnerability involving these variants before surgery. A lesser risk is associated with pneumatized anterior or posterior clinoid processes, also a product of excessive pneumatization of the sphenoid sinus.
A supraorbital cell may jeopardize the sterility of an operation when a neurosurgical approach to the orbit is used entering through the anterior cranial fossa [18,22].

This study aimed to observe the incidence of the following common anatomical variants in Melanesian skulls; agger nasi cells, concha bullosa, Haller's cells, internal carotid canal bulging in the sphenoid sinus, paradoxical curvature of the middle turbinate, pneumatization of the crista galli and supraorbital cells. For comparison, studies from a wide range of countries were collated to evaluate the possibility of racial variation.

Table 1. The 41 skulls used in the study were from either coastal or hinterland locations.

Catalogue number	N (41)	Geographic area
84-117 - 84-127	8	Sepik River, Papua New Guinea
84-150	1	Aird River, Papua New Guinea
84-160	1	Madang District, Papua New Guinea
84-171 - 84-177	4	Isudau Village, Fife Bay, Papua New Guinea
84-183 -84-210	14	Papua New Guinea
84-211	1	Coastal Papua New Guinea
84-223 - 84-225	2	Manus Island, Admiralty group, Papua New Guinea
84-236	1	South New Britain, Papua New Guinea
84-238 - 84 241	3	Ablinghi Island, South New Britain, Papua New Guinea
84-270, 84-286	2	Tabar Island, East North New Ireland, Papua New Guinea
84-279	1	Bismarck Archepelago, New Ireland, Papua New Guinea
84-284	1	Namatanai, New Ireland, Papua New Guinea
84-287	1	New Ireland, Papua New Guinea
84-457	1	Botarmul Village, North West Malekula Island, New Hebrides (Vanuatu)

MATERIALS AND METHODS

Origin of skulls

The Melanesian crania used for this study form part of a collection of skeletal remains recovered from various coastal and hinterland locations throughout the Melanesian islands of Papua New Guinea and Vanuatu (Table 1) during the 1930's from trophy hoards and burial grounds [23].
The skulls are currently housed in the Shellshear Museum, Discipline of Anatomy and Histology, University of Sydney. The 41 skulls were adults (as determined by tooth eruption and closure of the basilar suture), devoid of pathology and fully intact in the region of the paranasal sinuses. The skulls could not be reliably sexed, as the pelves for each skull were not available for a full assessment. The samples were not chosen randomly as the criteria used for their initial acquisition are not known and the selection from the museum collection was based on the skulls physical condition.

Image acquisition and analysis

Each skull was scanned using a Sytec 3000 General Electric Medical CT Scanner obtaining series of 1.5 mm slices of each skull. The exposure settings were 80-120 kV and 100-250 mA, which were optimised for each skull. The images were then reformatted and transferred to a PC for further analysis. Sienet Magicview 300 DICOM CD browser was used to view the reformatted images obtained from the scans. Sequential coronal, parasagittal and transverse slices were used to observe each of the variants.

Definitions of variants that can be observed

Agger nasi cells

Agger nasi cells are the most anterior of the anterior ethmoid cells and are situated in the lateral nasal wall, anterior and superior to the insertion of the middle concha [21] and inferior to the frontal recess [24]. Of the common anatomical variants, agger nasi cells are perceived to occur very frequently.

Concha Bullosa

Pneumatization of the inferior, middle and superior conchae may be noted [24], however, "true" concha bullosa only occurs when the middle concha becomes aerated in both the horizontal and vertical parts.

Haller's cells

Ethmoid cells from the anterior or posterior ethmoid sinuses may extend laterally and below the orbit encroaching on the maxillary sinus. These infraorbital cells are also known as Haller's cells [9] and have been investigated by a large number of authors [2,12,25-29].

Internal carotid bulge in the sphenoid sinus

When the sphenoid sinus is extensively pneumatized it may extend as far as the clinoid processes posteriorly. In some cases the internal carotid artery can be seen creating a bulge in the lateral or posterior wall of the sphenoid sinus and often there is only a thin lamina separating the artery from the sinus cavity that may be dehiscent [21].

Paradoxical middle turbinate

In some instances the curvature of the middle turbinate is seen to develop medial to lateral instead of lateral to medial [18]. This paradoxical curvature of the turbinate is not pathogenic but is clearly observed on coronal CT scans.

Pneumatization of the crista galli

Pneumatization of the crista galli usually occurs from the frontal sinus [14], but has not been implicated in sinus disease.

Supraorbital cells

Supraorbital cells are formed from the anterior ethmoid group and extend laterally above the orbit posterior to the frontal sinus within the frontal bone [18]. Their presence is best observed on coronal CTs.

Literature search for racial influence

A literature search was performed to obtain incidences from other geographical regions to compare with the present study. The exact racial composition of the other individual studies is not often specified so only the countries or regions in which the studies were performed are stated. However, it is probably reasonable to assume the race of the individuals in the samples are of the expected dominant racial group for that country, with the possible exception of the USA. In order to compare racial groups it was necessary to pool the data from countries whose dominant racial group was evident. In most instances it was either Mongoloid or Caucasoid. In all cases the incidences reported were of pooled sexes.

Statistics

The collective incidence was then used to perform chi square tests for significance at the 95% confidence level. For instances where incidences of five or less were involved Yates' correction and Fisher's exact tests were calculated.

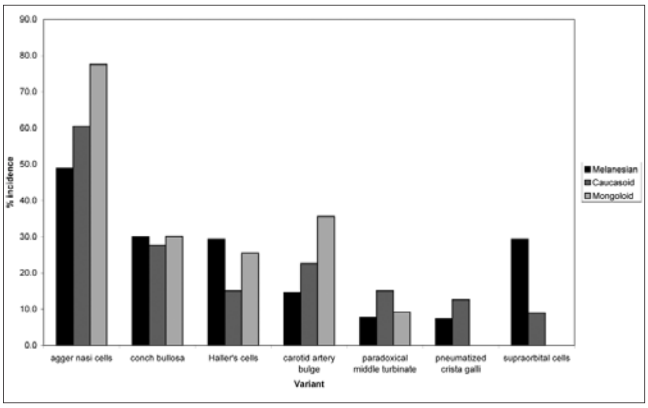

Figure 1. Comparison of common anatomical variants in Melanesians, Caucasoids and Mongoloids.

RESULTS

Comparison of common anatomical variants in Melanesians, Caucasoids and Mongoloids are presented in Figure 1. The incidences for the seven variants observed in the Melanesian samples are further worked out and presented in Tables 2 - 6 including the chi square p values for individual population comparisons.

Agger Nasi Cells

Agger nasi cells were the most frequently observed variant in Melanesians at 48.8% (Table 2). They were found unilaterally in ten cases (24.4%), seven on the right side and three on the left side. The right side was not found to be significantly dominant ($p = 0.077$). Of the 12 studies compared, four populations, British [2], Hong Kong Chinese [2], Turkish [24] and North Americans [31], were found not to be significantly different from Melanesians, although two studies showed significantly smaller differences of British [10] and Turkish [30] populations. Ethnic

Table 2. Agger nasi cell incidence in Melanesians compared to worldwide studies, significant p values are in bold.

Author(s)	Population	Racial Group	n/N	% Incidence	X2	p values Yates' correction	Fisher's exact test
Present study	Melanesian Islands	Australoid	20/41	48.8	1.000	1.000	1.000
Kayalioglu et al., 2000 [30]	Turkey	Caucasoid	4/82	4.9	0.000	0.000	0.000
Lloyd et al., 1991 [10]	UK	Caucasoid	14/100	14.0	0.000	0.000	0.000
Kantarci et al., 2004 [24]	Turkey	Caucasoid	241/512	47.0	0.832	0.964	0.872
Badia et al., 2005 [2]	UK	Caucasoid	63/100	63.0	0.119	0.171	0.135
Davis, 1914 [31]	USA	Caucasoid	65/100	65.0	0.074	0.110	0.089
Chaiyasate et al., 2007 [32]	Belgium	Caucasoid	36/50	72.0	0.023	0.040	0.031
Van Alyea, 1951 [25]	USA	Caucasoid	89/100	89.0	0.000	0.000	0.000
Bolger et al., 1991 [9]	USA	Caucasoid	199/202	98.5	0.000	0.000	0.000
Perez-Pinas et al., 2000 [28]	Spain	Caucasoid	110/110	100.0	0.000	0.000	0.000
Badia et al., 2005 [2]	Hong Kong	Mongoloid	56/100	56.0	0.435	0.552	0.462
Tonai and Baba, 1996 [29]	Japan	Mongoloid	67/75	88.9	0.000	0.000	0.000
Nitinavakarn et al., 2005 [33]	Thailand	Mongoloid	81/88	92.0	0.000	0.000	0.000

Table 3. Concha bullosa incidence in Melanesians compared to worldwide studies, significant p values are in bold.

					p values		
Author(s)	**Population**	**Racial Group**	**n/N**	**% Incidence**	**X^2**	**Yates' correction**	**Fisher's exact test**
Present study	Melanesian Islands	Australoid	12/40	30.0	1.000	1.000	1.000
Sanchez-Fernandes et al., 2000 (34)	Spain	Caucasoid	18/217	8.3	0.000	0.000	0.000
Bolger et al., 1991 (9)	USA	Caucasoid	32/202	15.7	0.034	0.058	0.043
Meloni et al., 1992 (22)	Italy	Caucasoid	22/106	20.8	0.238	0.337	0.274
Lloyd et al., 1991 (10)	UK	Caucasoid	24/100	24.0	0.463	0.603	0.522
Yousem et al., 1991 (35)	USA	Caucasoid	48/200	24.0	0.424	0.549	0.428
Perez-Pinas et al., 2000 (28)	Spain	Caucasoid	27/110	24.5	0.500	0.644	0.531
Kayalioglu et al., 2000 (30)	Turkey	Caucasoid	22/82	26.8	0.714	0.879	0.830
Calhoun et al., 1990 (8)	USA	Caucasoid	29/100	29.0	0.906	0.929	1.000
Arslan et al., 2004 (18)	Turkey	Caucasoid	60/200	30.0	1.000	0.850	1.000
Badia et al., 2005 (2)	UK	Caucasoid	43/100	43.0	0.307	0.407	0.183
Chaiyasate et al., 2007 (32)	Belgium	Caucasoid	34/50	68.0	0.000	0.001	0.001
Scribano et al., 1997 (12)	Italy	Caucasoid	67/73	91.8	0.000	0.000	0.000
Badia et al., 2005 (2)	Hong Kong	Mongoloid	15/100	15.0	0.042	0.073	0.057
Tonai and Baba, 1996 (29)	Japan	Mongoloid	21/75	27.8	0.821	1.000	0.832
Nitinavakarn et al., 2005 (33)	Thailand	Mongoloid	43/88	48.9	0.046	0.071	0.055

Table 4. Haller's cell incidence in Melanesians compared to worldwide studies, significant p values are in bold.

					p values		
Author(s)	**Population**	**Racial Group**	**n/N**	**% Incidence**	**X^2**	**Yates' correction**	**Fisher's exact test**
Present study	Melanesian Islands	Australoid	12/41	29.3	1.000	1.000	1.000
Perez-Pinas et al., 2000 (28)	Spain	Caucasoid	3/110	2.7	0.000	0.000	0.000
Sanchez-Fernandes et al., 2000 (34)	Spain	Caucasoid	7/219	3.2	0.000	0.000	0.000
Kayalioglu et al., 2000 (30)	Turkey	Caucasoid	3/82	3.7	0.000	0.000	0.000
Arslan et al., 2004 (18)	Turkey	Caucasoid	12/200	6.0	0.000	0.000	0.000
Kainz and Stammberger, 1992 (27)	Austria	Caucasoid	4/52	8.0	0.006	0.014	0.011
Kennedy et al., 1990 (26)	USA	Caucasoid		10.0	0.004	0.009	0.009
Schatz and Becker, 1984 (36)	USA	Caucasoid		10.0	0.004	0.009	0.009
Meloni et al., 1992 (22)	Italy	Caucasoid	11/106	10.4	0.005	0.010	0.010
Van Alyea, 1951 (25)	USA	Caucasoid	11/100	11.0	0.008	0.016	0.012
Chaiyasate et al., 2007 (32)	Belgium	Caucasoid	6/50	12.0	0.040	0.073	0.063
Lloyd et al., 1991 (10)	UK	Caucasoid	15/100	15.0	0.051	0.085	0.061
Badia et al., 2005 (2)	UK	Caucasoid	18/100	18.0	0.138	0.208	0.174
Kantarci et al., 2004 (24)	Turkey	Caucasoid	92/512	18.0	0.075	0.116	0.094
Scribano et al., 1997 (12)	Italy	Caucasoid	24/73	32.9	0.691	0.852	0.834
Bolger et al., 1991 (9)	USA	Caucasoid	91/202	45.1	0.062	0.091	0.082
Badia et al., 2005 (2)	Hong Kong	Mongoloid	9/100	9.0	0.002	0.005	0.004
Nitinavakarn et al., 2005 (33)	Thailand	Mongoloid	29/88	33.0	0.676	0.830	0.839
Tonai and Baba, 1996 (29)	Japan	Mongoloid	29/75	38.9	0.311	0.418	0.417

group comparison revealed the prevalence in Mongoloids was significantly higher than in both Melanesians and Caucasoids ($p < 0.001$ in both cases).

Concha Bullosa

True middle turbinate concha bullosa was found in 30% of the Melanesian skulls scanned, three on the right side and four on the left side (Table 3). Significantly higher incidences were reported for Italy [12] (91.8 %), Belgium [32] (68%) and Thailand [33] (48.9%) and lower incidences for Chinese Hong Kong [2] (15%), USA [9] (15.7%) and Spain (34) (8.3%). The pooled data for Caucasoids and Mongoloids proved there was little difference between all groups ($p > 0.428$) including Melanesians. There was, however, a large amount of variability in the data of the Caucasoid group.

Haller's Cells

In this study, Haller's cells occurred in 29.3% of the Melanesian skulls scanned (Table 4). Of the 41 crania, eight (19.5%) displayed Haller's cells unilaterally, two on the right side and five on the left side (not statistically significant). The overall incidence for Melanesians is most comparable to Italy [12] (32.9%) and Thailand [33] (45.1%). Significantly lower incidences, $p < 0.04$, were reported for 11 of the 18 populations compared. Caucasoids were significantly less ($p < 0.012$) likely to have the variant compared to both Melanesians and Mongoloids when

Table 5. Carotid artery bulge in the sphenoid sinus incidence in Melanesians compared to worldwide studies, significant p values are in bold.

						p values	
Author(s)	**Population**	**Racial Group**	**n/N**	**% Incidence**	**X^2**	**Yates' correction**	**Fisher's exact test**
Present study	Melanesian Islands	Australoid	6/41	14.6	1.000	1.000	1.000
Kazkayasi et al., 2005 (38)	Turkey	Caucasoid	14/267	5.2	0.023	0.053	0.036
Badia et al., 2005 (2)	UK	Caucasoid	6/100	6.0	0.095	0.181	0.107
Arslan et al., 2004 (18)	Turkey	Caucasoid	16/200	8.0	0.229	0.296	0.229
Fuji et al., 1997 (20)	USA	Caucasoid	2/25	8.0	0.423	0.680	0.700
Basak et al., 2000 (39)	Turkey	Caucasoid	8/64	12.0	0.754	1.000	0.775
Van Alyea, 1951 (25)	USA	Caucasoid	14/100	14.0	0.920	0.867	1.000
Kantarci et al., 2004 (24)	Turkey	Caucasoid	123/512	24.0	0.000	0.000	0.248
Teatini et al., 1987 (19)	Italy	Caucasoid	49/68	72.0	0.002	0.003	0.000
Meloni et al., 1992 (22)	Italy	Caucasoid	93/106	87.7	0.000	0.000	0.000
Badia et al., 2005 (2)	Hong Kong	Mongoloid	0/100	0.0	0.000	0.001	0.000
Nitinavakarn et al., 2005 (33)	Thailand	Mongoloid	36/88	40.9	0.003	0.006	0.004
Tan and Ong, 2007 (37)	Singapore	Mongoloid	65/96	67.7	0.000	0.000	0.000

Table 6. Paradoxical middle turbinate incidence in Melanesians compared to worldwide studies, significant p values are in bold.

						p values	
Author(s)	**Population**	**Racial Group**	**n/N**	**% Incidence**	**X^2**	**Yates' correction**	**Fisher's exact test**
PPresent study	Melanesian Islands	Australoid	3/39	7.7	1.000	1.000	1.000
Yousem et al., 1991 (35)	USA	Caucasoid	2/100	2.0	0.105	0.266	0.134
Arslan et al., 2004 (18)	Turkey	Caucasoid	6/200	3.0	0.159	0.343	0.167
Kayalioglu et al., 2000 (30)	Turkey	Caucasoid	6/82	7.3	0.944	0.767	1.000
Perez-Pinas et al., 2000 (28)	Spain	Caucasoid	11/110	10.0	0.671	0.916	1.000
Calhoun et al., 1990 (8)	USA	Caucasoid	12/100	12.2	0.462	0.666	0.557
Lloyd et al., 1991 (10)	UK	Caucasoid	15/100	15.0	0.249	0.383	0.399
Earwaker, 1993 (14)	Australia	Caucasoid	136/800	17.0	0.127	0.192	0.183
Bolger et al., 1991 (9)	USA	Caucasoid	53/202	26.1	0.012	0.021	0.012
Badia et al., 2005 (2)	UK	Caucasoid	29/100	29.0	0.007	0.014	0.007
Badia et al., 2005 (2)	Hong Kong	Mongoloid	8/100	8.0	0.950	0.772	1.000
Tonai and Baba, 1996 (29)	Japan	Mongoloid	8/75	11.1	0.610	0.860	0.746

the data was pooled. No significant difference was found between the prevalence of Haller's cells in Melanesians and Mongoloids.

Internal Carotid Artery Bulging in the Sphenoid Sinus

A carotid artery bulge in the sphenoid sinus was found in 14.6% of the Melanesian skulls, once on the right and four times on the left (Table 5). Both Italian studies found significantly higher incidences with 72% (19) and 87.7% (22). Amongst the three Mongoloid populations, Hong Kong Chinese (2) did not show the variant at all compared to Thais (33) and Singaporeans (37) who both had high incidences of 40.9% and 67.7%, respectively. At an ethnic group level, Mongoloids were found to have a significantly higher incidence of the carotid artery bulging in the sphenoid sinus than both Melanesians and Caucasoids. There was however, no significant difference between Caucasoids and Melanesians.

The mean thickness of the bone in the bulge at the thinnest point was measured in the Melanesian skulls and was found to be 1.1 mm on average; some cases had a thickness of only 0.7 mm.

Paradoxical Middle Turbinate

The Melanesian skulls displayed a paradoxical middle turbinate in 7.7% of cases each occurring on the left side (Table 6). Only two populations had a significantly higher incidence, British (2) 29% and Americans (9) 26.1%. Badia and colleagues (2) reported significant differences between Hong Kong Chinese and UK Caucasoid patients in their study. A statistical difference between Mongoloids and Caucasoids was found: $p = 0.033$.

Pneumatized Crista Galli

The present study found a pneumatized crista galli in 7.3% of cases in Melanesians. This compares to 5.4% in one American (9) study and 2.4% in a Turiksh one (30). A second American study had a significantly higher prevalence of 24% (25). Although there were few cases to contribute, no statistical difference was found between the pooled Caucasoid data and Melanesians.

Supraorbital Cells

In the present study of Melanesians, the incidence of supraorbital cells was found to be 29.3%, occurring five times (12.2%) unilaterally and seven times (17.1 %) bilaterally. Two previous studies of supraorbital cells found them to occur in 6% of Turkish people [18] and in 15% in Americans [25]. Only the Turkish population had a statistically smaller incidence compared to Melanesians. There are too few studies to compare to be able to comment on the existence of racial variation.

DISCUSSION

Of the many common anatomical variants that occur in the paranasal sinuses and nasal cavity, seven were chosen because of their importance in functional endoscopic sinus surgery and the possibility that the incidence of some may vary significantly in certain populations. Comparisons between individual populations and Melanesians, the principal subjects of this study, were performed, as were comparisons between ethnic groups using pooled data.

Agger nasi cells were found to be relatively less common in Melanesians compared to all other studies and significantly lower than in Mongoloids. A high amount of variability was found in the Caucasoid data that ranged from 4.9% to 100%, conversely the variability amongst Mongoloid populations was low. It may be possible that Mongoloids do in fact have a higher incidence of agger nasi cells, averaging almost 80%.

Concha bullosa was the variant that had the most consistent prevalence across the three major groups with no statistical differences found when the data were pooled. Again a high amount of variability was found within the groups, especially amongst Caucasoids.

Haller's cells were found to occur in close to 30% of the Melanesian skulls and in a similar proportion of Mongoloids. Caucasoids have a lower incidence (14%) compared to both Melanesians and Mongoloids (29.3%). The Caucasoid data were variable with most having an incidence less than 18% and only two being greater than this.

The presence of a carotid artery bulge in the sphenoid sinus was relatively low in the Melanesian sample at 14.6%. It would appear that Italians are likely to have a very high prevalence of this variant. The reason for this is not clear and there is only one other European study with which to compare these results. These outlier incidences are responsible for the high degree of variability observed in the Caucasoid data. Even without excluding the Italian studies, Mongoloid incidences are generally higher than both Caucasoids and Melanesians.

Paradoxical middle turbinate is generally observed infrequently in Melanesians (7.7%) and other populations around the world. Again a high level of variability in the Caucasoid data is caused by two outlier populations, making the determination of racial variation unlikely despite a significant difference being calculated between Caucasoids and Mongoloids.

Very few studies were found for comparison concerning supraorbital cells and pneumatization of the crista galli. Because of this the authors do not wish to draw any conclusions about the existence of racial variation regarding these variants. It should be noted however, than a high frequency (29.3%) of supraorbital cells was observed in the Melanesian skulls.

In none of the chi square tests was the occurrence of the common anatomical variants found to be statistically more prevalent on one side or the other.

CONCLUSION

It is clear that a high degree of variability occurs with the paranasal sinuses and nasal cavities when incidences of the anatomical variants are compared. Therefore, a thorough preoperative assessment should always be undertaken before sinus surgery commences. Only some of the variants observed in this study can be said to display racial variation. These are agger nasi cells, Haller's cells and the internal carotid bulging into the sphenoid sinus, the latter being the only one studied here that is of critical concern. Surgeons should be aware of these to minimize the risk of complications.

It is apparent from comparative studies such as this that incidence discrepancies exist, even within single populations. Caucasoid variability was particularly high in many cases. This may be due to differing definitions of variants, different investigation techniques [3], or ill-defined samples. Special attention needs to be paid to these key areas for comparisons to have any practical meaning.

ACKNOWLEDGEMENTS

All CTs courtesy of Sydney CT & MR.

REFERENCES

1. Yeoh KH, Tan KK. The optic nerve in the posterior ethmoid in Asians. Acta Laryngol (Stock) 1994; 114: 329-336.
2. Badia L, Lund VJ, Wei W, Ho WK. Ethnic variation in sinonasal anatomy on CT-scanning. Rhinology. 2005; 43: 210-214.
3. Thanaviratananich S, Chaisiwamongkol K, Kraitraku S, Tangsawad W. The prevalence of an onodi cell in adult Thai cadavers. ENT- Ear, Nose & Throat J 2003; 82: 200-204.
4. Szilvassy J. Zur entwicklung der stirnhohlen. Anthopol Anz. 1981; 39: 139-149.
5. Strek P, Kaczanowski K, Skawina A, et al. The morphological evaluation of frontal sinuses in the Human skulls. Folia Morphol (Warsz) 1992; 51(4): 319-328.
6. Kawamura A, Kasai K, Aboshi H. Morphological variation of the frontal sinuses in Melanesians (Fiji) and Polynesians (Samoan) populations. J Oral Sci 1998; 40: 25-30.
7. Aydinlioglu A, Kavakhi A, Erdem S. Absence of frontal sinus in Turkish individuals. Yonsei Med J 2003; 44: 215-218.
8. Calhoun KH, Waggenspack GA, Simpson BC, et al. CT evaluation of the paranasal sinuses in symptomatic and asymptomatic populations. Otolaryngology Head Neck Surg 1991; 104: 480-483.
9. Bolger WE, Butzin CA, Parsons DS. Paranasal sinus bony anatomic variations and mucosal abnormalities: CT analysis for endoscopic sinus surgery. Laryngoscope 1990; 101: 56-64.

10. Lloyd DM, Lund MS, Scadding MD. CT of the paranasal sinuses and functional endoscopic surgery: a critical analysis of 100 symptomatic patients. J Laryngol Otol 1991; 105: 181-185.
11. Messerklinger W. On the drainage of the normal frontal sinus in man. Acta Otolaryngol (Stockh) 1967; 63: 176-81.
12. Scribano E, Ascent G, Loria G, et al. The role of the osteomeatal unit in anatomic variations in inflammatory disease of the maxillary sinuses. Euro J Radiol 1997; 24: 172-174.
13. Jones NS, Strobl A, Holland I. A study of the CT findings of 100 patients with rhinosinusitis and 100 controls. Clin Otolaryngol 1997; 22: 47-51.
14. Earwaker J. Anatomic variants in sinonasal CT. Radiographics 1993; 13: 381-415.
15. Zinreich J, Mattox DE, Kennedy DW, et al. Concha bullosa: CT evaluation. J Comp Assist Tomo 1988; 12: 778-784.
16. Sarna A, Hayman AL, Laine FJ, Taber KH. Coronal imaging of the osteomeatal unit: anatomy of 24 variants. J Comp Assist Tomo 2002; 26: 153-157.
17. Stammberger HR, Wolf G. Headaches and sinus disease: the endoscopic approach. Ann Oto Rhinol Laryngol 1988; 97: (suppl.134).
18. Arslan H, Aydinlioglu A, Bozkurt M, Egeli E. Anatomic variations of the paranasal sinuses: CT examination for endoscopic sinus surgery. Auris Nasus Larynx 1999; 26: 39-48.
19. Teatini G, Simonetti G, Salvolini U, et al. Computed tomography of the ethmoid labyrinth and adjacent structures. Ann Oto Rhinol Laryngol 1987; 96: 239-250.
20. Fuji K, Chambers SM, Rholon AL. Neurovascular relationships of the sphenoid sinus. A microsurgical study. J Neurosurg 1979; 50: 31-39.
21. Stammberger HR, Kennedy DW. Paranasal sinuses: anatomical terminology and nomenclature. The Anatomical Terminology Group. Ann Otol Rhinol Laryngol Supp 1997; 167: 7-16.
22. Meloni F, Mini R, Rovasio S, et al. Anatomic variations of surgical importance in ethmoid labyrinth and sphenoid sinus. A study of radiological anatomy. Surg Radiol Anat 1992; 14: 65-70.
23. Mckenzie-Smith Z. The J. L. shellshear museum of comparative and physical anthropology: A review and catalogue of the melanesian crania collection. 1984 Diss.
24. Kantarci M, Karasen MR, Alpe F, et al. Remarkable anatomic variations in paranasal sinus region and their clinical importance. Euro J Radiol 2004; 50: 296- 302.
25. Van Alyea OE. Nasal sinuses. An anatomic and clinical consideration. Baltimore, Williams and Wilkins Company, 1951.
26. Kennedy DW, Zinreich SJ, Hassab MH. The internal carotid artery relates to endoscopic sphenoethmoidectomy. Am J Rhinol 1990; 4: 7-10.
27. Kainz J, Stammberger H. Danger areas of the posterior rhinobasis. An endoscopic and anatomical-surgical study. Acta Otolaryngol (Stockh) 1992; 112: 852-861.
28. Perez-Pinas I, Sabate J, Carmona A, et al. Anatomical variations in the human paranasal sinus region studied by CT. J Anat 2000; 197: 221-227.
29. Tonai A, Baba S. Anatomic variants of the bone in sinonasal CT. Acta Otolaryngol (Stockh) Suppl 1996; 525: 9-13.
30. Davis W B. Nasal accessory sinus in Man. Philadelphia, W B Saunders Co., 1914.
31. Kayalioglu, G., Oyar, O. and Gvsa, F. Nasal cavity and paranasal sinus bony variations: A computed tomographic study. Rhinology 2000; 38: 108-113.
32. Chaiyasate S, Baron I, Clement P. Analysis of paranasal sinus development and anatomical variations: A CT study in twins. Clin Otolaryngol 2007; 32: 93-97.
33. Nitinavakarn B, Thanaviratananich S, Sangsilp N. Anatomical 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(6): 763-768.
34. Sanchez Fernandes JM, Anta Escuredo JA, Sanchez Del Rey A, Santaolalla Montoya F. Morphometric study of the paranasal sinuses in normal and pathological conditions. Acta Otolarygol 2000; 120: 273-278.
35. Yousem DM. Imaging of sinonasal inflammatory disease. Radiol 1993; 188: 303-314.
36. Schatz CJ, Becker TS. Normal Anatomy of the Paranasal Sinuses. Radiol Clin North Am 1984; 22: 107-118.
37. Tan HKK, Ong YK. Sphenoid sinus: An anatomic and endoscopic study in Asian cadavers. Clin Anat 2007; 20: 745-750.
38. Kazkayasi M, Karadeniz Y, Arikan OK. Anatomic Variations of the Sphenoid Sinus on Computed Tomography. Rhinology 2005; 43: 109-114.
39. Basak S, Akdilli A, Karaman CZ, Kunt T. Assessment of some important anatomical variations and dangerous areas of the paranasal sinuses by computed tomography in children. Int J Pedeatric Otorhinolaryngol 2000; 55: 81-89.

Mr Marcus Robinson
F13 Anderson Stuart Building
University of Sydney
NSW 2006 Australia

Tel: +61-2-9351 2816
Fax: +61-2-9351 2817
E-mail: marcusr@anatomy.usyd.edu.au