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Anatomical variations of the main septum of the sphenoidal sinus and its importance during transsphenoidal approaches to the sella turcica

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ABSTRACT

Background: There are numerous variations reported regarding anatomy of the sphenoidal sinuses that include e.g. their pneumatisation, septation and relation to neurovascular structures. The following study aimed to examine the height of the MS in the sphenoidal sinuses, as well as its type (bony, membranous or mixed) and its course amongst the adult Polish population.

Materials and methods: A retrospective analysis of 296 computed tomography (CT) images (147 females, 149 males) of the paranasal sinuses was conducted. Images in axial, coronal, and sagittal planes were visualised and analysed.

Results: The average height of the MS was 2.1 ± 0.41 cm for the entire research group. Completely bony MS was found in 32.77% of the patients, partially membranous in 63.85%, and solely membranous in 3.38% of the patients. The course of the MS that changed from the anterior to the posterior section of the sinuses predominated (83.78%). The MS had the shape of the letter 'C' in 22.29% of the cases (C-shaped in 11.82% and inverted 'C' in 10.47%). The rarest was the MS resembling letter 'S', which only appeared in 11.48% of the patients (S-shaped in 5.74% and inverted 'S' in 5.74%). Only 16.22% of the patients had the MS that shifted neither its course nor its shape.

Conclusions: The MS might be an intraoperative marker of the midline, providing surgeons with good spatial orientation. Notwithstanding, the MS changed its course in the majority of the studied here patients, hence more careful transsphenoidal approach is needed to avoid iatrogenic neurovascular injuries.

1. Introduction

The transnasal transsphenoidal approach was first introduced as the preferred means for surgical access to the sella turcica and its close surroundings by Cushing [1] and Hirsch [2] at the beginning of the 20th century. Undoubtedly, it has become an advantageous technique, used during surgical interventions undertaken for most intrasellar and parasellar neoplasms procedures [3]. Using the transnasal approach is less invasive than open craniotomy (which would also require the surgeon to retract the composite brain tissue) [3]. Henceforth, using this technique results in lower morbidity and mortality rates [4]. Endoscopic techniques provide a good insight into the barely accessible places, lessen the traumatisation to the site, and help with obtaining a shorter period of convalescence in comparison to the classical operations [5,6]. Moreover, using the transsphenoidal approach is also preferable in the paediatric population, as it does not impact the anatomic and functional integrity of the central nervous system and the skull, allowing the young patient to grow up without any major impairments [7].

Pneumatic spaces known as the sphenoidal sinuses are localised in the diaphysis of the sphenoid bone and are lined with mucous membrane. Their morphology is varied to a great extent. They differ in size,

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shape, number of septa present, and the degree to which they fill with air [8–11]. The closeness of nervous and vascular structures (neighboring with the sinuses' walls), as well as their own anatomy, are of dire importance whilst undergoing a surgery in this region.

During the transnasal transsphenoidal approach, it is imperative for a surgeon to have a good spatial orientation within the sinus in order to perform a safe and effective procedure. One of the iatrogenic injuries that may prove fatal for the patient is damaging the internal carotid artery; therefore, otorhinolaryngologists should be aware of the midline and know its location, so as not to cause a critical hemorrhage from it [12,13]. Medical professionals utilize the intrasinus septation as a landmark for the midline (where it is typically attached to), as well as a marker for identification of the location of the sella turcica [13,14].

Evaluation of sinuses' anatomical parameters before the invasive intervention (surgery or endoscopy) is crucial, in furtherance of diminishing the surgical risk and avoiding potential complications during the surgery [5,15–24]. One of the most accurate methods of obtaining images of the paranasal sinuses is via computed tomography (CT). Variations in the anatomical structure of the sinuses can be detected by utilising this method, owing to the exact representation of the osseous structures.

Being aware of the importance of having a surgical orientation within the sphenoidal sinuses during the transsphenoidal approach to the sella turcica, the following study aimed to present the height, morphological type, and course of the main septum in the axial plane in patients of Polish origin. The secondary outcomes involved probing for sources of heterogeneity by the means of subgroup analysis of females and males in order to find any statistically significant differences between sexes.

2. Materials and methods

The study was conducted as a retrospective analysis of 296 CTs of Polish patients (147 females, 149 males) who were referred to the Department of Medical Imaging of the University Hospital in Kraków, Poland. Patients over 18 years of age who did not present with a pathology in the sphenoidal sinuses were included in the research. The study exclusion criteria comprised also of patients with a head trauma or nasal, orbital or cranial basis surgery undergone in the past.

A spiral CT scanner (Siemens Somatom Sensation 16) was used to obtain the images in this study. A standard procedure was applied, in the option Siemens CARE Dose 4D, without the use of any contrast medium. In order to glean images in the sagittal and coronal planes, a secondary reconstruction tool (multiplans reconstruction – MPR) was used after obtaining images in the axial planes. While analysing the imaging data, diagnostic station Siemens Volume Wizard was used.

The radiological evaluation of the obtained images involved height and morphological type in the coronal plane, as well as course of the main septum (MS) in the axial plane. The height was measured in centimetres on the images in the coronal plane, from the inferior to the superior wall of the sphenoidal sinuses by drawing a straight line (if the MS was regarded as straight – Fig. 1) or a curved line (if the MS was regarded as irregular – Fig. 2) whilst using the software. In each case, the absolute height of the MS was measured.

Whilst evaluating the morphological type of the MS, we have measured its density by analyzing absorption of X-rays relative to five threshold values in the Hounsfield units (H.u.): 200 H.u., −100 H.u., 0 H.u., 100 H.u., and 200 H.u. The completely bony MS was considered as such when its density did not fall below 200 H.u. Conversely, the incompletely bony MS (partially membranous) was considered as such when density of a part of the septum was below 200 H.u. (up to −200 H.u.).

The septum regarded as undergoing a course shift was considered as such when it changed its direction in the paranasal sinuses from the median or the medial to the lateral side (relative to the median line). The complete course of the MS was recorded and classified into subgroups.

Fig. 1. CT of the paranasal sinuses, coronal plane. A straight main septum.

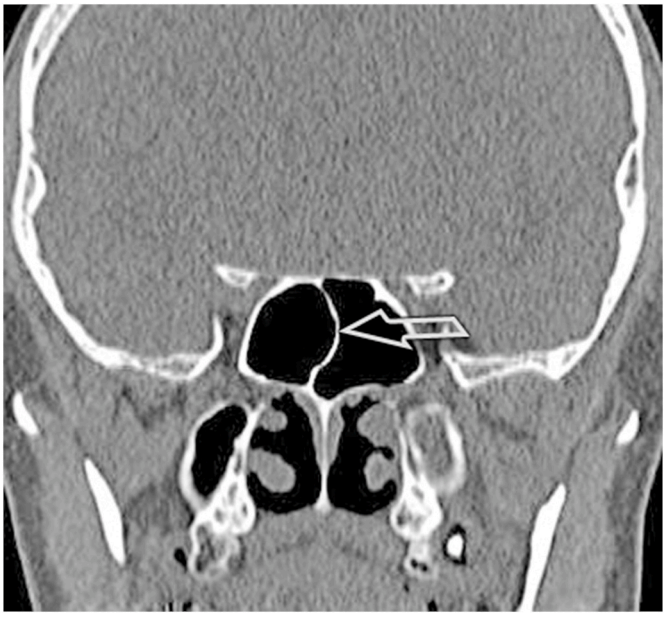

Fig. 2. CT of the paranasal sinuses, coronal plane. An irregularly shaped main septum.

Statistical analysis was conducted with the help of STATISTICA version 13.3 by TIBCO Software Inc®. The t-Student test for the independent variables was applied while evaluating the differences between sexes in terms of the septum's height. The said discrepancies were probed for in terms of the morphological type and the septum's course by utilising the Chi^2 test. A statistically significant value of $p < 0.05$ was chosen for all the results.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

For this type of study, formal consent is not required.

Table 1
The height of the main septum (MS) in centimeters.

Height of the MS (cm)	F	M	F + M
Average	2	2.15	2.1
Standard deviation	0.38	0.43	0.41
The lowest	1.14	0.72	0.72
The highest	3.25	3.21	3.25

F – number of females, M – number of males.

3. Results

3.1. Height of the MS

In each case the height of the MS was measured by using a straight line running parallel to the septum (when the MS was considered as straight – Fig. 1) or curved (when the septum was considered irregular – Fig. 2) on the images in the coronal plane. The average height of the MS was 2.1 ± 0.41 cm (in the range of 0.72–3.25 cm) for the whole research group. A statistically significant difference was found between the females and males in the average height of the MS ($p = 0.001$, t-Student test for the independent variables). Females had a lower average of the MS (2.00 ± 0.38 cm in the interval of 0.72–3.21 cm) than the males did (2.15 ± 0.43 cm in the interval of 1.14–3.25 cm) (Table 1, Fig. 3).

3.2. Morphological type of the MS

A completely bony MS was found in 97 patients (53 females, 44 males). In 189 cases (90 females, 99 males), the MS was partially membranous. The rarest variant was the MS that did not undergo even partial ossification – the membranous one, which was observed in only 10 individuals (4 females, 6 males).

No statistically significant differences were found between the males and females in regards to the septum's type ($p = 0.438$, Chi^2 test). The percentage distribution of the types of the MS is very approximate for both sexes. In both groups, the partially membranous MS predominates (around 60–65%) (Table 2, Figs. 4–6).

3.3. Course of the MS in the axial plane

A deflection in the course of the MS was most often visible from the anterior to the posterior part of the sphenoidal sinuses. Such situation took place in 248 of the cases (120 females, 128 males, Table 3). In 96 patients (45 females, 51 males), there was a clear shift to the lateral side of only the posterior part of the septum; in 54 of them (23 females, 31 males), the MS shifted to the right side, and in 42 of them (22 females, 20 males) to the left side. Fifty-two patients (23 females, 29 males) had a septum that changed its course to the lateral side in both anterior and

Table 2
The type of the main septum – bony, partially membranous, membranous.

The type of the MS	F	F%	M	M%	F + M	F + M%
Bony	53	36.05%	44	29.53%	97	32.77%
Partially membranous	90	**61.22%**	99	**66.44%**	189	**63.85%**
Membranous	4	2.72%	6	4.03%	10	3.38%

MS – main septum, F – number of females, F% – the percentage derived from all the females studied, M – number of males, M% – the percentage derived from all the males studied.

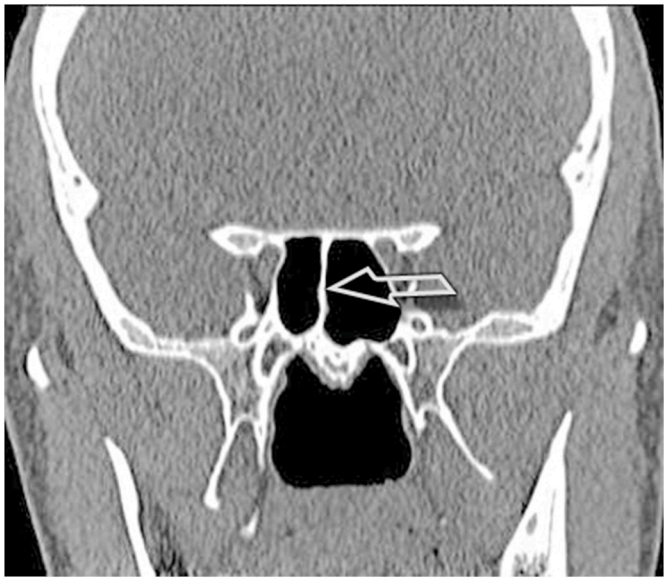

Fig. 4. CT of the paranasal sinuses, coronal plane. A completely bony main septum.

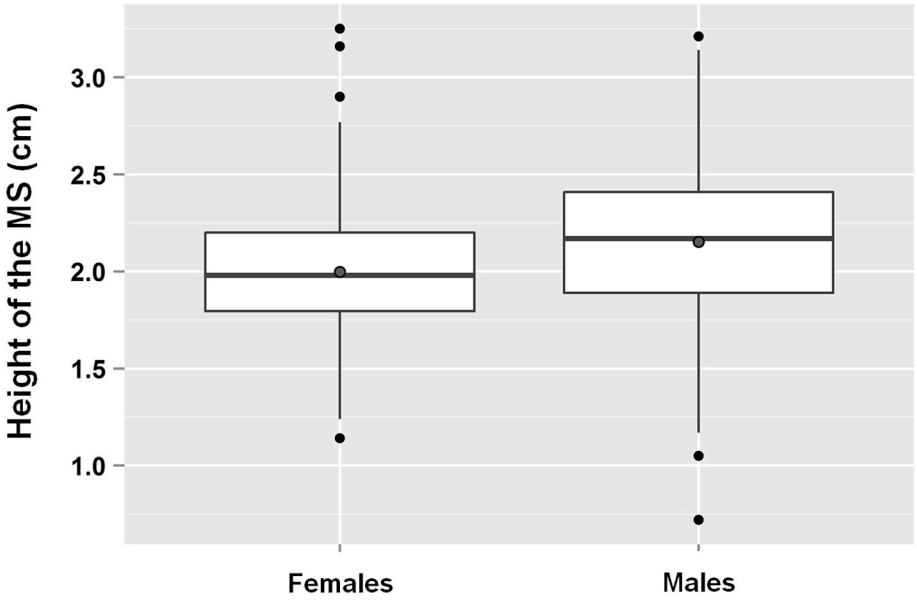

Fig. 3. The box plot distribution of the height of the main septum in the females and males.
The horizontal line represents the median value in the respective group. The box represents the value of the lower quartile (Q1) and the upper quartile (Q3). The whiskers (the vertical lines) represent the range of the data. The average values in each group were marked as dots (located in the proximity to the median values). The dots outside the whiskers represent the outliers.

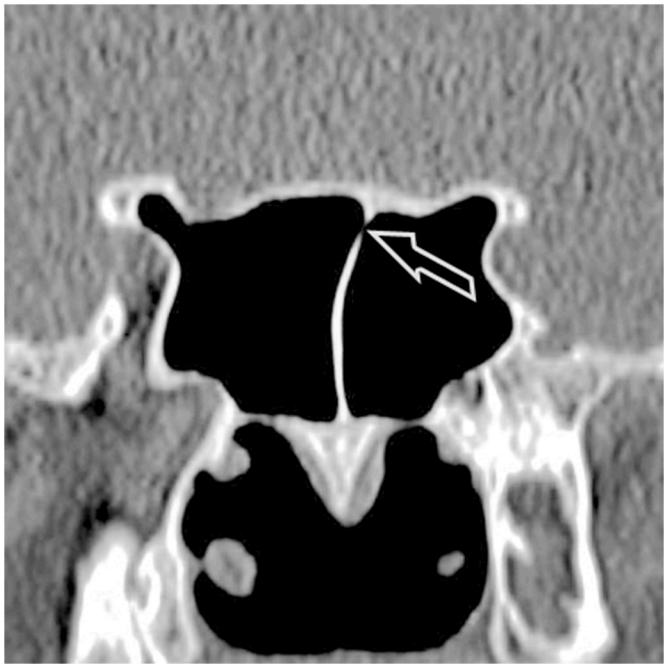

Fig. 5. CT of the paranasal sinuses, coronal plane. A partially membranous main septum (the arrow points to the membranous part of the septum).

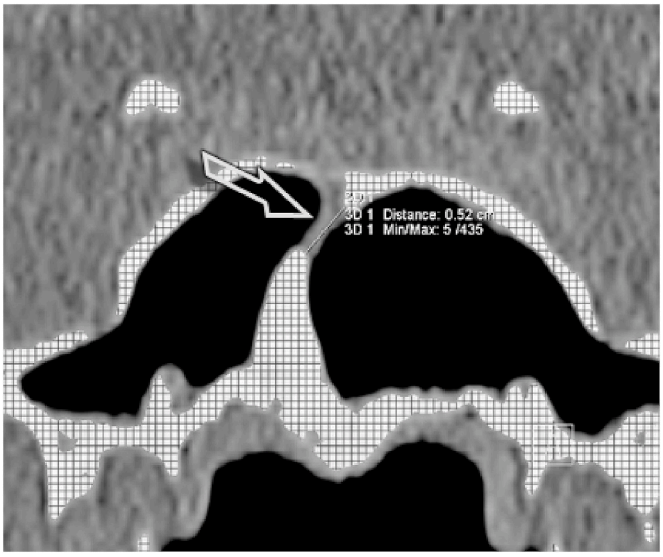

Fig. 6. CT of the paranasal sinuses, coronal plane. A partially membranous septum (the membranous part of the septum is measured on the image).

Table 3
The course of the main septum (MS).

The course of the MS	F	F%	M	M%	F + M	F + M%
Non-median course	120	**81.63%**	128	**85.91%**	248	**83.78%**
Median course	27	18.37%	21	14.09%	48	16.22%

MS – main septum, non-median course – the MS shifting its course from the anterior to the posterior part of the sphenoid sinuses, F – number of females, F% – the percentage derived from all the females studied, M – number of males, M % – the percentage derived from all the males studied.

posterior parts, but in 28 cases (11 females, 17 males) it occurred from the left side to the right side, and in 24 cases (12 females, 12 males) from the right side to the left side (Table 4, Figs. 7–10).

Table 4
The non-median course of the main septum shifting its direction from the anterior to the posterior part of the sphenoidal sinuses.

The course of the MS	F	F%	M	M%	F + M	F + M%
Posterior Right	23	**15.65%**	31	**20.81%**	54	**18.24%**
Posterior Left	22	14.97%	20	13.42%	42	14.19%
Anterior and Posterior Right	11	7.48%	17	11.41%	28	9.46%
Anterior and Posterior Left	12	8.16%	12	8.05%	24	8.11%
'C'	17	11.56%	18	12.08%	35	11.82%
Inverted 'C'	16	10.88%	15	10.07%	31	10.47%
'S'	12	8.16%	5	3.36%	17	5.74%
Inverted 'S'	7	4.76%	10	6.71%	17	5.74%

MS – main septum, F – number of females, F% – the percentage derived from all the females studied, M – number of males, M% – the percentage derived from all the males studied, posterior right – the shift of only the posterior part of the septum to the right, posterior left – the shift of only the posterior part of the septum to the left, anterior and posterior right – the shift of both the anterior and posterior parts of the septum to the right, anterior and posterior left – the shift of both the anterior and posterior parts of the septum to the left, 'C' – the MS in the shape of letter 'C,' inverted 'C' – the MS in the shape of the inverted letter 'C,' 'S' – the MS in the shape of the letter 'S,' inverted 'S' – the MS in the shape of the inverted letter 'S.'

Fig. 7. CT of the paranasal sinuses, axial plane. The shift of only the posterior part of the septum to the right.

The MS took the shape of the letter 'C' in 66 patients (33 females, 33 males), 35 of whom had the typical shape of the letter 'C' (17 females, 18 males); in 31 cases it resembled an inverted letter 'C' (16 females, 15 males). The rarest variant of the MS was shifting of its course - when it paralleled the letter 'S' shape – was seen in 34 patients (19 females, 15 males), where in 17 cases it took the shape of the typical letter 'S' (12 females, 5 males), and in 17 patients it resembled the inverted letter 'S' (7 females, 10 males). In only 48 patients (27 females, 21 males) the MS shifted neither its course nor its shape, and had the median course in the sagittal plane from the anterior to the posterior part of the sinuses (Table 4, Figs. 11–15).

No statistically significant relations were found between the types of the course of the MS and sex ($p = 0.19$, Chi^2 test). The percentage distribution of the aforementioned types is very approximate between both males and females. In 80% of females and 80% of males, the MS had a different course to the median one. No statistical significance was

Fig. 8. CT of the paranasal sinuses, axial plane. The shift of only the posterior part of the septum to the left.

Fig. 9. CT of the paranasal sinuses, axial plane. The shift of both the anterior and posterior parts of the septum to the right.

noticed while analysing the relations between the various course of the MS and sex ($p = 0.561$, Chi^2 test). In both groups of males and females, the percentage distribution of the course of the MS is very similar (Tables 3 and 4).

When the MS shifted its course, in 32 cases (10 females, 22 males) it co-formed a part of the posterior wall of one of the sphenoidal sinuses: the right sphenoidal sinus in 21 cases (6 females, 15 males), and the left sphenoidal sinus in 11 cases (4 females, 7 males). The co-formation of the part of the wall of the right sphenoidal sinus took place in 10 patients (5 females, 5 males) whose posterior part of the MS shifted to the right and in 11 patients (1 female, 10 males) whose anterior and posterior parts of the MS shifted from the left to the right. The co-formation of the part of the wall of the left sphenoidal sinus was visible in all 11 patients (4 females, 7 males) where the posterior part of the MS solely shifted to the left (Table 5, Fig. 16).

A statistically significant relation was found between the type of the co-formation of a part of the posterior wall of the sinus, or its absence, with sex ($p = 0.036$, Chi^2 test). The co-formation of a part of the posterior wall of the left sphenoidal sinus with the shift of both anterior and posterior parts of the MS to the left was not taken into consideration in this part of the study, since its prevalence was 0% in both females and males (Table 5). The analysis of the results shows that for the co-formation of a part of the posterior wall of the right sphenoidal sinus with the shift in the posterior part of the MS to the right, as well as the change's absence, appear with the same frequency in both groups, females and males; however, the two remaining types are definitely more common in the male group – 10 out of the 11 cases (90.9%) where the co-formation of a part of the posterior wall of the right sphenoidal sinus with the shift of both anterior and posterior parts of the MS to the right were males, and 7 out of 11 cases (63.6%) where the co-formation of a part of the posterior wall of the left sphenoidal sinus with the shift of only the posterior part of the MS to the left were also males (Table 5).

4. Discussion

Although endoscopic access to the sphenoidal sinuses using the transnasal approach does not usually present with major obstacles [25], anatomical variations in this area are common. Due to these possible variations, what would otherwise be a routine intervention in typical instances might prove a challenge to an inexperienced surgeon. Henceforth, a medical imaging examination using CT is necessary in order for the surgeon to be better prepared. Moreover, in case a patient has been operated on previously or their anatomy is altered by a pathological process, it is crucial to conduct imaging and neuronavigation examinations prior to treatment [26,27]. Furthermore, newest research conducted by Stecco et al. [28] suggests incorporating the use of virtual dissection tables (VDT) whilst diagnosing complicated facial trauma cases, as shown in their research on Le Fort fractures (all types involve the pterygoid process of the sphenoid bone in some extent). Doubtful cases seen on the Picture Archiving and Communication System (PACS) were more confidently identified with integration of VDT in the process [28].

In the present study, the average height of the MS was found to be 2.075 cm (range of 0.72–3.25 cm). From the presented CT examples, it can be noted that the total height of the septum relies strongly upon its course in the coronal plane (straight or curved). In almost every case studied here, the MS was curved, and its height was usually different from the height of the sphenoidal sinuses. To our knowledge, no other studies have mentioned the height of the MS of the sphenoidal sinuses. Sareen et al. [24] noted that the vertical dimension of the sphenoidal sinuses is on average 2.2 cm (range of 1.4–3.6 cm). Stokovic et al. [29] have found it to be 0.96 cm and 1.2 cm for the 2 conchal sinuses they found, on average 1.75 cm for the presellar type, 1.98 cm for the sellar type and 2.15 cm for the postsellar type of the sphenoidal sinuses. According to our study, the vertical dimension of the sphenoidal sinuses is the same as the vertical dimension of the MS only when the MS has a straight course.

The most common morphological type of the MS found in our study was the mixed type – a partially ossified, partially membranous septum that was present in 63.85% of the patients. A completely ossified septum was found in 32.77% of patients. The rarest type of the MS – noticed in only 3.38% of cases was the completely membranous type. In reports from the literature regarding this topic, only Dundar et al. [30] made note of the frequency prevalence of the completely and the

Fig. 10. CT of the paranasal sinuses, axial plane. The shift of both the anterior and posterior parts of the septum to the left.

Fig. 11. CT of the paranasal sinuses, axial plane. The main septum in the shape of the letter 'C.'

Fig. 12. CT of the paranasal sinuses, axial plane. The main septum in the shape of the inverted letter 'C.'

Fig. 13. CT of the paranasal sinuses, axial plane. The main septum in the shape of the letter 'S.'

incompletely ossified MS. However, their results differ significantly – they estimated the completely ossified MS as 60.5% of cases (132/218), and not fully ossified as 30.2% of cases, but they did not find any completely membranous MS in the research material of the CTs of 218 patients [30]. Nonetheless, the aforementioned authors did not state the method of measuring or the inclusion criteria used to classify the MS into each type. The said criteria may have had a fundamental relation to the dissimilar results, as well as the ethnic group used in the study – Turkish.

Not only is the anatomy of the sphenoidal sinuses of immense importance for the transsphenoidal approach to the sella turcica and the pituitary gland, but it is also of interest during functional endoscopic sinus surgery. It is said to be the method of choice for non-neoplastic lesions, such as chronic infectious and polypoid sinusitis [31]. With this approach, otorhinolaryngologists should keep in mind the possibility of encountering a non-completely main bony septum, being sure to pay careful attention while moving within the lumen of the sinus. If the surgeon is not attentive to the movement of the surgical instruments, they might in these instances cause iatrogenic injury to the membranous or the mixed type of the MS, resulting in its perforation.

The shift in the course of the MS was seen in 83.78% of the patients, while no shift of the MS (the median course) was observed in 16.22% of the patients. The most common variant of the course of the MS was the

Fig. 14. CT of the paranasal sinuses, axial plane. The main septum in the shape of the inverted letter 'S.'

Fig. 15. CT of the paranasal sinuses, axial plane. The median course of the main septum.

shift of only the posterior part of the MS to the right (18.24%); the rarest type was the course of the MS in the shape of the letter 'S' (5.74%) and inverted letter 'S' (5.74%). The remaining variants were found with a similar frequency: the shift of only the posterior part of the MS to the left occurred in 14.19% of patients, the shift of both the anterior and posterior parts of the MS to the right occurred in 9.46%, the shift of both the anterior and posterior parts of the MS to the left appeared in 8.11%, the course of the MS in the shape of the letter 'C' was reported in 11.82%, and the course of the MS in the shape of the inverted letter 'C' was found in 10.47% of patients.

Table 5
Co-formation of a part of the posterior wall of the sinus not dominated by the main septum (MS).

	F	F%	M	M%	F + M	F + M%
RSS MS posterior right	5	**3.4%**	5	**3.36%**	10	3.38%
RSS MS anterior and posterior right	1	0.68%	10	**6.71%**	11	**3.72%**
LSS MS posterior left	4	2.72%	7	4.7%	11	**3.72%**
LSS MS anterior and posterior left	0	0%	0	0%	0	0%

RSS – co-formation of a part of the posterior wall of the right sphenoid sinus, MS posterior right – the course of the MS with the shift of only the posterior part to the right, MS anterior and posterior right – the course of the MS with the shift of both anterior and posterior parts to the right, LSS – co-formation of a part of the posterior wall of the left sphenoid sinus, MS posterior left – the course of the MS with the shift of only the posterior part to the left, MS anterior and posterior left – the course of the MS with the shift of both anterior and posterior parts to the left.

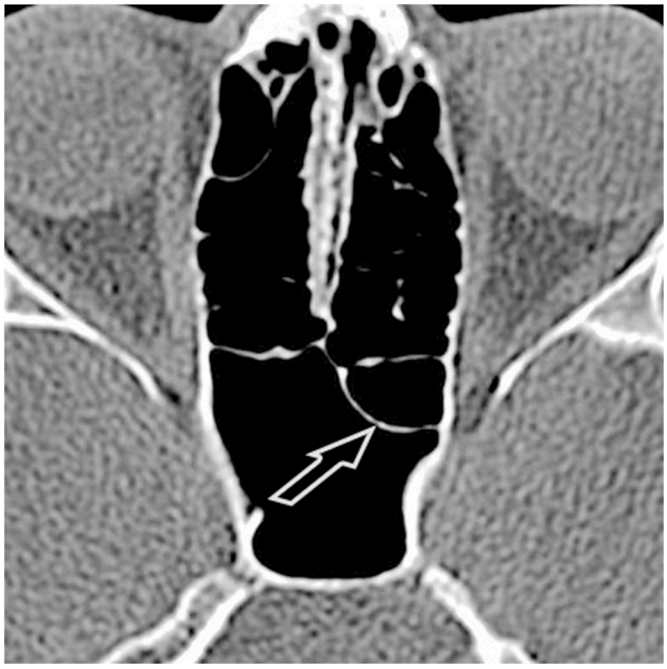

Fig. 16. CT of the paranasal sinuses, axial plane. The dominant right sphenoidal sinus. The course of the MS shifts to the left and contributes to the posterior wall of the left sphenoidal sinus (non-dominant).

Similar results were reported by Tan and Ong [32] who studied 48 cadavers and noted the median/medial course of the MS in 16.6% of cases (8/48), deflecting to the right in 27.1% of cases (13/48), and deflecting to the left in 56.3% of cases (27/48). Furthermore, Battal et al. [33] found in their research material (314 CTs) that the MS followed the median course in 17.7% of patients, whereas the shift to the right was seen in 43.3% of the patients and the shift to the left in 38.9% of the cases. Comparable results were found by Hammer and Radberg [34], who reported the median course of the MS as 25%. The aforementioned authors noticed that the MS may have a median course only in the anterior part and shift its course in the posterior part, either to the left or to the right; in some cases it may be "scoliotic" in its course [34]. Elwany et al. [35] found a median course of the MS in 27% of the cases, the shift of only the posterior part of the sinus in 43% (without providing the side), the shift of both anterior and posterior parts of the MS in 30% (without stating the side), a letter 'C' shape of the MS in 18% (without the distinction between the letter 'C' and inverted letter 'C'), and the letter 'S' shape in 8% (without specifying it as either letter 'S' or inverted letter 'S'). Anusha et al. [36] reported a median course of the

MS in 28.67% of the cases, deflecting to the right in 10.33%, and deflecting to the left in 14.67%.

Different results were reported by Kinnman [37], who found a median course of the MS in 40% of cases (32/80), a shift to the right in 33.75% of cases (27/80), and a shift to the left in 21.25% of cases (17/80). The discrepancy in the results may arise from the medical imaging method (X-ray of the sinuses) and from the patients included in the study (they suffered from acromegaly). Lupascu et al. [38] described a median course of the MS in 38% of the cases in their study (200 CTs). Lee et al. [39] reported a twofold higher frequency prevalence of the median course of the MS, observing it in 32% of their patients (32/100); these results may possibly come down to the ethnic group studied (Korean). According to some Turkish authors, there was definitely a greater frequency of the MS running in the median: 64% [30]. Furthermore, in the remaining cases, the MS deflected to the right or left [30]. Moreover, Kayalioglu et al. [31] stated the course of the MS as median in 64% of cases, but the given results refer only to the MS's course when a single septum was seen (22 skulls) and not to all of the 48 skulls examined. Idowu et al. [40] have found the MS to be attached in the midline in its anterior part in 65% of the cases, but shifted to the right posteriorly in 38%, though providing no more specific details that would allow us to assign it to specific categories.

Sareen et al. [24] found that the course of the MS is not always median. According to their study, the MS frequently shifts laterally or superiorly while running towards the posterior part of the sphenoidal sinuses [24]. Likewise, Tan and Chong [41] stated that the MS often deflects towards one side of the sinuses, and Cope [42] described the course of the MS as usually median and anteroposterior, noting that it may slightly deflect from the midline. Nonetheless, Yune et al. [43] reported that the MS almost never runs in the median. However, these authors provide neither the direction nor the frequency prevalence of the shifting septum course (Table 6).

During the trans-sphenoidal approach to the sellar floor, a surgeon must at all times be aware of the midline so as to be cautious of the presence of regional neurovascular anatomical entities, i.e., the internal carotid artery, the cavernous sinus, and the optic nerves [44]. The patient's anatomy might become misleading, especially during re-operation but also if the sinus itself has a very complicated and varied anatomy (e.g., multiple septa) or if it is not pneumatised [44,45].

One such landmark is the intrasinus septation that is said to indicate the crucial point for the surgery midline, therefore providing the otorhinolaryngologists with orientation of the sella [46], the skull base, and the nearby neurovascular structures [47]. If on preoperative CT of the sinuses a midline septum is identified, it can then be used as a direct marker of it during the operation [46]. As suggested by Hayashi et al. [46], should the MS be found away from the midline, it can still be used as an indirect landmark by calculating the distance between the midline and the septum on CT and thus helping the surgeon to know roughly where important structures lie.

There are authors who state that should the septum not be placed at the midline, or when absent, that the transsphenoidal approach might be reconsidered [48]. Henceforth, a surgeon should not jump to the conclusion that the intersinus septum is always located in the midline, but should instead make use of CT, which will point out the exact location of the midline, and then plan the surgery accordingly. As another means of identifying the midline, some authors have proposed using the vomer instead [49].

Quite often, the MS is removed during surgery in order to obtain better visualization of the sinus, as well as to provide a broader space for the approach to sellar lesions [50]. Ahmadipour et al. [50] found that in almost a third of their cases, the septum formed a part of the carotid canal. Henceforth, we would like to acknowledge the concerns raised by these authors [50] and Twigg et al. [51] regarding the possibility that if the surgeon removes the septum with a diamond drill or the thru-cut forceps, they might iatrogenically injure the internal carotid artery, causing a potentially fatal hemorrhage.

In addition to the aforementioned variants of the MS, Jaworek-Troć et al. [9] have noted that in the Polish, there is more than a single septum in 78.04% of patients and most commonly, two additional septa (32.09%) are present; together with the MS, these additional septa accounted for the total of three septa dividing the sphenoidal sinus into four chambers. Lastly, Garcia-Garrigos et al. [3] noted situations in

Table 6
The frequency prevalence of the course of the main septum (MS) in the published literature.

Author (materials and methods)	med.	right	left	post. right	post. left	ant./post. right	ant./post. left	'C'	inv. 'C'	'S'	inv. 'S'
	%										
Tan and Ong 2007 (48 skulls, endoscopic and dissection study)	16.6	27.1	56.3	–	–	–	–	–	–	–	–
Battal et al., 2014 (314 CT angiography)	17.7	43.3	38.9	–	–	–	–	–	–	–	–
Hammer and Radberg 1961 (120 skulls in RTG and CT scans and 103 RTG)	25	–	–	–	–	–	–	–	–	–	–
Elwany et al., 1983 (100 RTG, 100 RTG skulls, 50 skulls – dissection study)	27	–	–	43		30		18		8	
Anusha et al., 2015 (300 CT scans)	28.67	–	–	10.33	14.67	–	–	–	–	–	–
Kinnman 1977 (80 skulls, dissection study)	40	33.75	21.25	–	–	–	–	–	–	–	–
Lupascu et al., 2014 (200 CT scans)	38	–	–	–	–	–	–	–	–	–	–
Lee et al., 2003 (100 CT scans)	32	–	–	–	–	–	–	–	–	–	–
Dundar et al., 2014 (218 CT scans)	64	–	–	–	–	–	–	–	–	–	–
Kayalioglu et al., 2005 (180 MRI scans, 77 skulls – dissection study)	64	–	–	–	–	–	–	–	–	–	–
Sareen et al., 2005 (20 skulls, dissection study)	?										
Tan and Chong 2001 (–)	?										
Cope 1917 (–)	?										
Yune et al., 1975 (–)	?										
Jaworek-Troć et al., current study (296 CT scans)	16.22	27.7[a]	22.3[b]	18.24	14.19	9.46	8.11	11.82	10.47	5.74	5.74

Med. – median course, right – shift to the right, left – shift to the left, post. right – shift of only the posterior part of the septum to the right, post. left – shift of only the posterior part of the septum to the left, ant./post. right – shift of both the anterior and posterior parts of the septum to the right, ant./post. left - shift of both the anterior and posterior parts of the septum to the left, 'C' – the course in the shape of the letter 'C', inv. 'C' – the course in the shape of the inverted letter 'C', 'S' – the course in the shape of the letter 'S', inv. 'S' – the course in the shape of the inverted letter 'S', ? – the authors were aware of the occurring shift in the course of the MS but did not provide numerical values.

[a] Sum of post. right and ant./post. right.

[b] Sum of post. left and ant./post. left.

which the additional septa created a cruciform appearance of the sinus, resembling the structure of the Onodi cells. All the factors mentioned here may prove a challenge during a procedure within the sphenoidal sinuses, potentially leading to severe complications such as blindness due to optic nerve injury or cerebrospinal fluid fistula [25,52].

5. Conclusions

This study found that the height, morphological type, and course of the MS in the axial plane of the sphenoidal sinuses vary greatly. The average height of the MS was found to be 2.1 ± 0.41 cm for the entire research group. The majority of the patients had a mixed type of MS (partially ossified, partially membranous). Furthermore, it was found that the MS changes its course the most often from the anterior to the posterior section of the sphenoidal sinuses. In the majority of patients studied, only shifting of the posterior part of the septum to the right was visible. In order to avert potential complications while carrying out a planned surgical intervention in this region, CT is recommended due to the high incidence of anatomical variants of the sphenoidal sinuses.

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Ethical statement

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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CRediT authorship contribution statement

Joanna Jaworek-Troć: Conceptualization, Methodology, Data curation, Investigation, Formal analysis, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration. **Joe Iwanaga:** Methodology, Writing - review & editing, Supervision. **Robert Chrzan:** Conceptualization, Data curation, Investigation, Writing - review & editing, Supervision. **Jacek J. Zarzecki:** Investigation, Formal analysis, Writing - original draft, Visualization. **Paulina Żmuda:** Investigation, Formal analysis, Writing - original draft, Visualization. **Agata Pękala:** Methodology, Data curation, Investigation, Formal analysis, Writing - original draft. **Iwona M. Tomaszewska:** Methodology, Writing - review & editing, Supervision. **R. Shane Tubbs:** Methodology, Writing - review & editing, Supervision. **Jarosław Zawiliński:** Conceptualization, Methodology, Data curation, Investigation, Writing - review & editing, Visualization, Supervision. **Michał P. Zarzecki:** Conceptualization, Methodology, Investigation, Formal analysis, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration.

Declaration of competing interest

The authors declare no conflicting interests with the current study.

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