The Journal of International Advanced Otology

J Int Adv Otol 2021; 17(1): 23-9 • DOI: 10.5152/iao.2020.8927

Original Article

Effect of Sigmoid Sinus Position on the Difficulty and Approaches to Cochlear Implantation Surgery

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Cite this article as: Galal A, Caruso A, Lauda L, Eldin OG, Baki F, Sanna M. Effect of Sigmoid Sinus Position on the Difficulty and Approaches to Cochlear Implantation Surgery. J Int Adv Otol 2021; 17(1): 23-9.

OBJECTIVES: To assess the effect of the position of the SS on CI regarding the ability to perform posterior tympanotomy, round window visibility, and mastoid pneumatization.

MATERIALS and METHODS: This is a prospective study, including 65 adult patients with CI performed at our center during 2017. We used 3 methods to assess SS position using a computed tomography (CT) scan. Lee's line passing through the tympanic segment of the facial nerve. Park's line passing through the facial nerve and round window membrane. Our proposed method using a parallel line from the external auditory canal and passing through the facial nerve. Relation to mastoid pneumatization on CT and to intraoperative round window visibility were assessed in relation to intraoperative position of the SS.

RESULTS: The method by Park et al. was statistically significant ($p<0.001$); however, a cutoff point could not be set. Lee's method was statistically insignificant ($p=0.091$). Our proposed method was statistically significant with a cutoff point at ≤2.46 mm ($p=0.001$). SS position did not affect pneumatization nor round window visibility.

CONCLUSION: The position of SS preoperatively using a CT might suggest the inability to perform posterior tympanotomy and the need to change side or approach. However, it does not affect neither mastoid pneumatization nor visibility of the round window niche through the facial recess.

KEYWORDS: Anterior sigmoid sinus, sigmoid sinus position, cochlear implant

INTRODUCTION

Cochlear implantation (CI) is the established treatment for bilateral severe to profound hearing loss and is extending to unilateral loss, tinnitus [1], and auditory neuropathy [2], and an ever-expanding audiological criteria [3]. The classic transmastoid facial recess approach remains the most commonly used approach and is frequently judged for being affected by the surrounding anatomical variations [4, 5], one of which is the sigmoid sinus (SS) location.

The formation of the temporal venous system starts at 1 month of intrauterine life with the vena capitis medialis, which would be replaced by the vena capitis lateralis or primitive head sinus. This would give rise to the straight sinus, transverse sinus, and SS at around 3 months of intrauterine life [6].

The SS sigmoid sinus originates at the junction of the transverse and the superior petrosal sinuses at the superior border of the petrous bone [6]. From this point on, it changes direction in the vertical plane toward the medial portion of the mastoid cavity in an S form and terminates at the jugular bulb [7]. It is the posterior limit of the mastoid bone. The sino-dural angle is formed at the junction of the SS and superior petrosal sinus and the dura [8]. The variability of the location of the SS is a well-established fact [9].

The anteriorly located SS might increase time and difficulty of the surgery and if injured risks massive bleeding [10]. Furthermore, if far displaced anteriorly, it might affect the visibility of round window niche (RWN) through posterior tympanotomy (PT) or even prevent performing mastoidectomy [11].

Many methods have assessed the SS position; however, these were either unclearly described or too complicated for daily use or with no intraoperative or radiological correlation, which limited their clinical use [7, 9, 12-14]. Very few publications tackled this issue avoiding the abovementioned limitations [13, 15].

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Submitted: 06.09.2020 • **Revision Received:** 08.04.2020 • **Accepted:** 08.28.2020
Available online at www.advancedotology.org

This study aimed to demonstrate a simple method using high-resolution computed tomography (HRCT) to anticipate the SS position that might prevent PT and necessitate a change in approach or side of CI preoperatively. This was based on a modification of the Kashio et al. [16] method for round window visibility. We then compared it to valid clinically applicable methods in the literature. It also aimed at assessing other aspects of the effect of SS on CI surgery, namely effect on visibility of RWN through PT and effect of its position on mastoid pneumatization.

MATERIALS AND METHODS

Patients

A total of 65 adult patients with CI performed at our center between February 2016 and February 2017 with no sex barriers were included in this study. Severe to profound hearing loss on the operated side was the audiological indication (some of our cases were unilateral). Round window membrane (RWM) insertion was intended in all patients.

We excluded patients with previous middle ear surgeries or revision CI and history of middle ear diseases such as chronic suppurative otitis media or cholesteatoma. We also excluded congenital anomalies within the middle ear or cochlear duct on HRCT and major trauma or fractures to the skull.

Patients in this study were published in a previous separate paper to assess various methods to assess RWN depth. The SS assessment was not tackled in that study [17].

Methods

Preoperative assessment was performed using HRCT of the temporal bone (TB) with (0.5 mm) thickness cuts in the bone window. All measures were performed preoperatively with the surgeon blinded to their results.

SS position was assessed in the axial view by 3 methods:

a. Park's method (Figure 1 left): A line through the mid- RWM and facial nerve (FN), measuring the distance to the most prominent part of the SS by a line perpendicular to this line. This was accomplished at the cut with the widest basal turn (BT) of cochlea [15].
b. Lee's method (Figure 1 right): Passing a line through the cut with the longest tympanic segment of the FN and determining whether SS would be anterior, tangential, or posterior to it [13].
c. Our proposed method (Figure 2): Line A is a line passing through both the bony cartilaginous junction and tympanic annulus representing the posterior wall of the external auditory canal (EAC), first described by Kashio et al. [16] If these 2 lines did not coincide in the same cut, line A was transposed to the cut with widest BT.

Line B is a line that passes through the anteromedial part of the FN and parallel to the EAC at the cut with the widest BT of cochlea (line A).

The perpendicular distance between line B and the most prominent part of the SS at the axial cut with widest BT of cochlea represented the relevant distance of our method.

Intraoperative assessment: SS position was classified into:

a. Normal: when SS was not seen in the microscopic field.
b. Moderate: when SS occupied part of the microscopic field.
c. Anterior: when SS was occupying most of the microscopic field, but PT was feasible.
d. Very anterior: when SS was so anterior that PT could not be performed, and the intervention was shifted to subtotal petrosectomy (STP).

In addition, intraoperative SS position was compared with RWN visibility through PT. This visibility was divided into completely visible, partially visible, and invisible. SS position was also compared with the degree of mastoid pneumatization on CT, which was classified into cellular, moderately sclerosed, and totally sclerosed.

Radiological measurements were performed using RadiAnt DICOM viewer free software (Medixant, Poznan, Poland).

Statistical Analysis

Data were fed to the computer and analyzed using the Statistical Package for the Social Sciences (IBM SPSS) software package version 20.0 (IBM Corp.; Armonk, NY, USA). Qualitative data were described using number and percent. The Kolmogorov-Smirnov test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard deviation, median and interquartile range (IQR). Significance of the obtained results was judged at the 5% level.

RESULTS

The total number of patients was 65. Of these 35 (53.8%) were women and the rest men. All were adults with a mean age of 60.3 years with a range from 18 to 83 years. Right-sided CI was performed in

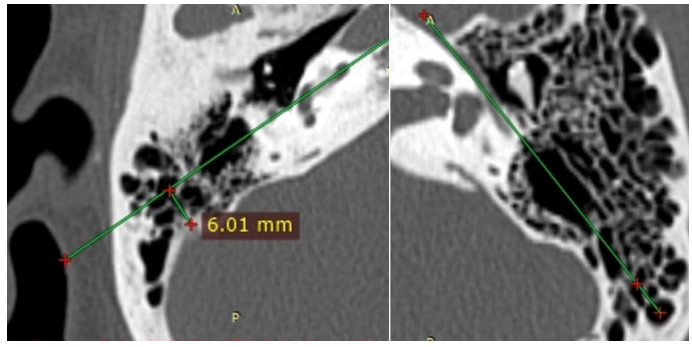

Figure 1. Left: Park's method for sigmoid sinus position (right ear). Right: Lee's method (left ear)

MAIN POINTS

- Sigmoid sinus if located far anteriorly can prevent the performance of classical transmastoid facial recess approach.
- Based on the above, awareness of alternative approaches to cochlear implantation is crucial
- Sigmoid sinus location and mastoid pneumatization are not related. Consequently, a sigmoid sinus can be located anteriorly in a pneumatized mastoid and vice versa.
- If sigmoid sinus location allowed posterior tympanotomy, it does not affect RWN through it.

Table 1. Correlation between SS, IO, and the method of Park et al. (mm) (n=65)

	SS position IO											
	Normal (n=31)		Moderate (n=20)		Anterior (n=10)		Very anterior (n=4)		Total		Test of significance	p
	No.	%	No.	%	No.	%	No.	%	No.	%		
Park's method (mm)(CT)												
Minus	0	0.0	0	0.0	1	10.0	3	75.0	4	6.2	χ^2=16.570	^{MC}p=<0.001*
Positive	31	100.0	20	100.0	9	90.0	1	25.0	61	93.8		
Min–Max	0.0–13.60		0.0–8.44		0.0–7.0				0.0–13.60		H=25.794*	<0.001*
Mean±SD	6.59±3.04		3.24±2.33		1.54±2.25		0.0		4.64±3.38			
Median	6.17		2.78		1.23				4.24			

SS: sigmoid sinus; IO: intraoperative assessment; CT: computed tomography; SD: standard deviation.

χ^2: chi-squared test for comparing the 2 groups.

^{MC}p: p value for Monte Carlo for chi-squared test for comparing the 2 groups.

H,p: H and p values for Kruskal-Wallis test

*: Statistically significant at p≤0.05

Table 2. Correlation between SS position, IO, and HRCT imaging according to Lee's method (n=65)

	SS position IO									
	Normal (n=31)		Moderate (n=20)		Anterior (n=10)		Very anterior (n=4)		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
SS position according to Lee's line (CT)										
Posterior	13	41.9	3	15.0	1	10.0	0	0.0	17	26.2
Tangential	11	35.5	8	40.0	3	30.0	1	25.0	23	35.4
Anterior	7	22.6	9	45.0	6	60.0	3	75.0	25	38.5
Total	31	100.0	20	100.0	10	100.0	4	100.0	65	100.0
χ^2(^{MC}p)	10.006 (0.091)									

SS: sigmoid sinus; IO: intraoperative assessment; HRCT: high-resolution computed tomography; CT: computed tomography.

χ^2: chi-squared test for comparing the different categories.

^{MC}p: p value for Monte Carlo for chi-squared test for comparing the different categories.

*: Statistically significant at p≤0.05

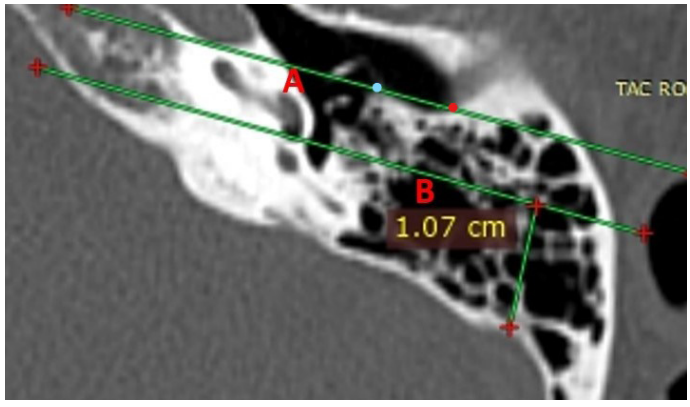

Figure 2. Left axial CT showing our proposed method for sigmoid sinus position. A line of the plane of the external auditory canal, blue dot: tympanic annulus, red dot: bony cartilaginous junction. B line parallel to A passing through anteromedial surface of the mastoid FN

37/65 (56.9%) and left-sided CI in the rest. Of all the patients, 4 were converted into STP because of far anterior SS by an intraoperative decision.

The method proposed by Park et al. was statistically significant (p<0.001) using chi-squared and Kruskal-Wallis tests (Table 1). However, 4/65 (6.2%) patients had negative values. A cutoff point could not be set for this method because out of the 4 patients with a very anterior SS, 3 presented with negative values. Accordingly, it was statistically inapplicable to set a cutoff point for a single patient against 61. However, the method proposed by Lee et al. was statistically insignificant, using chi-squared and Kruskal-Wallis tests (p=0.091) (Table 2)

Our proposed method was statistically significant (p<0.001) (Table 3). As our method did not give any negative values, the cutoff point could be detected at ≤2.46 mm with a significance of p=0.001, using analysis of variance test (Table 4). Figure 3 shows 1 of the 4 patients turned into STP with both our proposed method and that of Park's giving a negative result.

There was no statistical significance between mastoid pneumatization on CT and intraoperative assessment (IO) position of the SS. None of the 4 sclerosed mastoids had their SS anterior (n=61) since pneumatization could not be well assessed in patients with far anterior sigmoid (Table 5).

Table 3. Correlation between SS position, IO, and our proposed method (n=65)

	SS position IO						
	Normal (posterior) (n=31)	Moderate (tangential) (n=20)	Anterior (n=10)	Very anterior (n=4)	Total (n=65)	F	p
Our method (mm)(CT)							
Min–Max	7.04–18.50	3.94–14.0	2.46–11.70	0.0–2.99	0.0–18.50	23.063*	<0.001*
Mean±SD	11.52±2.98	7.67±2.38	6.55±2.95	1.50±1.25	8.95±3.90		
Median	10.80	7.51	5.70	1.50	8.81		

SS: sigmoid sinus; IO: intraoperative assessment; CT: computed tomography; SD: standard deviation.

F,p: F and p values for analysis of variance test

*: Statistically significant at p≤0.05

Table 4. Agreement (sensitivity, specificity) for our proposed method for SS position (in mm) to predict very anterior SS

	AUC	p	95% C.I	Cutoff	Sensitivity	Specificity	PPV	NPV
Our method (mm)	0.996*	0.001*	0.983–1.009	≤2.46	75.0	98.36	75.0	98.4

SS: sigmoid sinus; AUC: area under a curve; C.I: confidence intervals; PPV: positive predictive value; NPV: negative predictive value.

*: Statistically significant at p≤0.05

Table 5. Relationship between mastoid pneumatization (CT) and SS position IO (n= 61)

	Mastoid pneumatization (CT)							
	Cellular (n=31)		Moderate sclerosis (n=26)		Sclerosed (n=4)		Total	
	No.	%	No.	%	No.	%	No.	%
SS position IO								
Normal	20	64.5	8	30.8	3	75.0	31	50.8
Moderate	8	25.8	11	42.3	1	25.0	20	32.8
Anterior	3	9.7	7	26.9	0	0.0	10	16.4
Total	31	100.0	26	100.0	4	100.0	61	100.0
χ^2 (^{MC}p)	8.182 (0.078)							

CT: computed tomography; SS: sigmoid sinus; IO: intraoperative assessment.

χ^2: chi-squared test for comparing the different categories.

^{MC}p: p value for Monte Carlo for chi-squared test for comparing the different categories.

The intraoperative position of the SS did not affect the visibility of the RWN through PT (p=0.698) (Table 6) (n=61) since in the 4 patients turned into STP, therefore, visibility through PT was impractical.

DISCUSSION

The SS sigmoid sinus position is well-known to be variable [6], and it is also accepted among otologists that this can increase the difficulty of different otologic procedures [13]. CI surgery might be affected by the position of SS in 3 aspects, namely performing mastoidectomy and PT, relation to pneumatization, and effect on RWN visualization. All the patients had normal TBs with no history of disease or trauma.

Regarding SS position, Kayalioglu et al. [7] published an anatomical study with no radiological correlation. It measured length and width of the SS and compared differences on both sides. Neither sex nor age of these bones were stated. Differences between sides were significant.

In another study, Icchico et al. [12] compared the unilateral chronic ear with the contralateral normal ear in the same patient. They classified SS according to the relation between width and depth on axial CT to protrusive, half-moon, and saucer. The thickness of the CT cuts was high (2 mm). We think that this method was descriptive of SS protrusion, not its effect on surgical difficulty, as it did not correlate to any fixed bony structure. Furthermore, it was not mentioned at which level to perform the measurement. They stated that regardless of the disease, the right SS was significantly bigger and more protrusive.

Others defined anterior SS on CT when there was no distance between anterior most part of the SS and posterior most part of the EAC [11, 14]. It is worth mentioning that exact points of reference for this measurement were not clearly described. In addition, both were radiological assessments with no intraoperative correlation. Others also used EAC as a landmark for SS position using various methods, including cadaveric and CT and reported the mean to vary from 8 to 24 mm [7, 9, 18, 19]. They all, however, applied no comparison to the

Table 6. Relationship between RWN visibility through PT and SS position IO (n=61)

	RWN visibility through PT (IO)							
	Invisible (n=3)		Partially visible (n=18)		Fully visible (n=40)		Total	
	No.	%	No.	%	No.	%	No.	%
SS position IO								
Normal	2	66.7	9	50.0	20	50.0	31	50.8
Moderate	0	0.0	7	38.9	13	32.5	20	32.8
Anterior	1	33.3	2	11.1	7	17.5	10	16.4
Total	3	100.0	18	100.0	40	100.0	61	100.0
χ^2(^{MC}p)	2.365 (0.698)							

RWN: round window niche; PT: posterior tympanotomy; SS: sigmoid sinus; IO: intraoperative assessment.

χ^2: chi-squared test for comparing the different categories.

^{MC}p: p value for Monte Carlo for chi-squared test for comparing the different categories.

IO situation. Wooley et al. [20] measured the distance between the EAC and the most prominent part of SS on axial CT scan where SS, BT, and EAC were simultaneously present. However, this was rarely possible in our hands. Additionally, They did not perform intraoperative correlation either and stated that anteriorly located sigmoid did not affect complication rate or electrode insertion but prolonged operative time. It is worth mentioning that this study included only children and included pathological ears. They reported the value of this measurement to have a mean of 13.5 mm [20]. Other landmarks such as the spine of Henle and lateral semicircular canal were used by other authors [9].

Lee [13] performed a retrospective study with neither radiological nor intraoperative correlation. It consisted of a line passing through the tympanic FN, and they suggested that it affected the accessibility of PT. We applied this method in our study and compared it to the intraoperative SS location, which the original authors did not perform. It was statistically insignificant (p=0.091). One explanation could be that since the tympanic segment course is not always fixed, it has variable angulation with the mastoid segment [21]. This means that SS with the same position can give different results with this method owing to differences in the angulation of the course of the tympanic segment of the FN.

Park et al. [15] studied the position of the SS on axial CT and correlated it to intraoperative difficulty. They drew a line bisecting RWM and FN and measured the distance between it and the most prominent part of the SS. This line only takes into consideration the relation of the FN to SS and omits the EAC. This line also would be affected by the rotation the BT of the cochlea in relation to EAC, which is variable from one patient to another [16, 22]. It did not give statistical difference on the difficulty of surgery in the original study [15]. In this study, we compared this method to the location of the SS during surgery directly since difficulty is subjective. It was statistically significant (p=0.001), but we obtained 4/61 (6.5%) patients with negative values. Only 1 of the 4 very anterior SS was positive. This led to inapplicability to look for a cutoff point.

On the basis of the aforementioned disadvantages of various methods, we suggest a simple measurement to overcome them. This was the distance between FN and SS. We passed a line parallel to the EAC that passes through the FN at the axial cut with the widest BT of cochlea (Kashio line) [16]. This line was originally used to predict the visibility of RWN through PT. We used it for a new purpose, which is measuring the distance between it and the most prominent point of the SS to assess its position. In our view and in accordance with the literature, the 2 most important structures in relation to SS that can affect the accessibility of FR (facial recess) and RWN through it are the EAC and the FN. Of the distance between the EAC and SS, the distance between FN and SS would be the most relevant to feasibility of PT. This was represented in our method. This method was not affected by the rotation of the BT of cochlea like Park's method nor with the angulation of tympanic segment of the FN as Lee's method. Moreover, no matter how far anterior the SS in our patients was, we never obtained a negative value. This method was statistically significant (p=0.001). We detected a cutoff point at 2.46 mm with a sensitivity of 75% and specificity of 98.36%. Consequently, when this measurement is ≤2.46 mm, there is a high possibility that PT would not be technically feasible.

We believe that the SS position affected the approach in 4 patients, where PT was impossible and all were converted to STP and blind end closure of the EAC by an intraoperative decision. It was stated in a study that if the anterior wall of the SS was anteriorly located, the canal wall up mastoidectomy might be impossible, and the study also reported that in 1.6% patients, PT could not be performed owing to anterior SS [11]. In our study, it was 4/65 patients (6.15%). Wooley reported that he did not encounter such a finding. Nevertheless, he suggested decompression of the SS as a solution if it happened [20]. However, we perform STP regularly for such an anatomical difficulty, especially in the case of an ipsilateral dominant SS because its probable injury during decompression might risk brain edema [23]. The suprameatal approach of Kronenberg [24] is a valid option. Another suggestion would be simply deciding to operate the other side in case of bilateral deafness in the absence of other contraindications.

There is an argument whether there is a relation between pneumatization of the TB and the location of SS. This was discussed by Han et al. [25] who classified SS according to pneumatization around it into anterior, around it, and posterior. This study also included pathological ears for correlation and applied complex 3D reconstruction. Shatz and Sade compared the distance of EAC to SS between pneumatized and

sclerotic TBs but included pathological ears and found statistical significance between both groups [18]. Turgut et al. [26] who performed their study on cadavers using x-ray did not find a correlation between both. Yet, they found a strong correlation between length of the mastoid and its pneumatization. In this study, we concur that there was no relation between pneumatization and SS location (p=0.078). We believe that the mastoid cavity can be contracted (low dura and/or anterior SS) though can be well pneumatized and vice versa. We excluded diseased TBs to exclude the probable effect of disease on mastoid cavity size.

The SS position did not affect the accessibility of the RWN through PT in this study, which contradicts results of some studies [27]. We believe that it might increase the difficulty or time of surgery. It can decrease the room for instruments. However, it did not affect the visibility of the RWN through PT. Therefore, the far anterior location of SS can hinder performing PT; however, it does not change its visibility when the PT could be performed.

In terms of limitations, any manual measurement method can have inter and intra-subject variability. Our measurements were performed by a single radiologist; therefore, inter-subject variability could exist. However, these measurements can be considered as a guide to warn about very anterior SS and increase preparedness of the surgeon preoperatively.

CONCLUSION

Both our proposed method and Park's method were significant in predicting very anterior SS. However, our method did not give negative values, and a cutoff point of <2.26 mm could be set for practical impossibility for PT, the need for an alternative approach depending on the center's experience of SMA, SS decompression, or STP. SS position did not affect RWN visibility when PT could be done and did not have any relation to mastoid pneumatization either.

Ethics Committee Approval: Ethical committee approval of both CDC of Piacenza and medical school of Alexandria University were obtained.

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – M.S., F.B.; Design – A.G., F.B.; Supervision – M.S., F.B., A.C., L.L.; Resource – A.C., L.L.; Materials – A.C., L.L.; Data Collection and/or Processing – A.G., O.G.E., A.C.; Analysis and/or Interpretation – A.G., O.G.E.; Literature Search – A.G., O.G.E., L.L.; Writing – A.G., F.B.; Critical Reviews – M.S., F.B.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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