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The contribution of sphenoidal electrodes placed under fluoroscopy in lateralization of bilateral refractory temporal lobe epilepsy: a clinical study

Floroskopi eşliğinde yerleştirilen sfenoidal elektrotların bilateral dirençli temporal lob epilepsisinde lateralizasyona olan katkısı: klinik çalışma

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Abstract

Aim: The aim of this study is to investigate the contribution of sphenoidal electrodes placed under fluoroscopic guidance to scalp electrodes, in the lateralization of temporal ictal onsets in bilateral refractory temporal lobe epilepsy. Also we determine the actual locations of sphenoidal electrodes by computerized tomography.

Materials and Methods: We performed a prospective study on 10 patients with intractable epilepsy who has underwent sphenoidal electrode placement from 2010 to 2012. Refractory temporal lobe epilepsy patients whose localization and lateralization of epileptic focus couldn't established with scalp EEG, or patients diagnosed bitemporal epilepsy with bitemporal seizure activity in video-EEG but no seizure onset identified, were evaluated. Sphenoidal electrodes placed double-sided to patients under sedation in the operating room. The control of the sphenoidal electrodes' last position and several parameters displayed with 3D tomography. Patients monitorized at video-EEG unit. Simultaneously sphenoidal electrodes and scalp electrodes recordings obtained. Sphenoidal electrode lateralization results are compared with MRI, PET, SCALP EEG lateralization.

Results: The utility rate of sphenoidal electrode recordings were found to be 28.1%. 2 of 10 cases lateralized were localized, 4 of 8 patients were lateralized by sphenoidal electrodes.

Conclusion: Sphenoidal electrodes and scalp electrodes are similar in their ability to detect seizures. The optimal placement of sphenoidal electrodes with our technique provided additional localizing and lateralizing information in this series.

Keywords: Sphenoidal electrode, refractory epilepsy, epilepsy surgery.

Öz

Amaç: *Bu çalışma bilateral temporal lob epilepsisinde temporal iktal başlangıçların lateralizasyonunun saptanmasında, floroskopi eşliğinde yerleştirilen sfenoidal elektrotların saçlı deri elektrotlara katkısını değerlendirmek amacıyla yapıldı. Aynı zamanda bilgisayarlı tomografi ile sfenoidal elektrotların foramen ovaleye yakınlığı değerlendirildi.*

Gereç ve Yöntem*: 2010-2012 tarihleri arasında dirençli epilepsi tanısı olan, sfenoidal elektrot taktığımız 10 hastanın prospektif çalışmasını yaptık. Dirençli temporal lob epilepsisi tanısı almış ancak skalp EEG ile epileptik odak lokalizasyonu ve lateralizasyonu yapılamamış ya da video-EEG de bitemporal nöbet aktivitesi saptanarak bitemporal epilepsi tanısı almış ancak nöbet başlangıcı saptanamayan olgular değerlendirildi.*

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Sfenoidal elektrotlar sedasyon altında ameliyathenede çift taraflı olarak takıldı. Sfenoidal elektrotların son pozisyonu ve birçok parametre 3D tomografide değerlendirildi. Hastalar video-EEG ünitesinde monitörize edildi. Eş zamanlı sfenoidal elektrot ve saçlı deri elektrot kayıtları alındı. Sfenoidal elektrot lateralizasyon sonuçları MR, PET ve saçlı deri EEG lateralizasyonu ile karşılaştırıldı.

Bulgular: *Sfenoidal elektrotların yararlılık oranı %28,1 olarak saptandı. Lateralizasyonu yapılamamış 10 olgunun ikisi lokalize, sekiz olgunun dördü lateralize edilmiştir.*

Sonuç: *Literatürde sfenoidal elektrotların kullanımı ve yararlılıkları hakkında yapılan en önemli eleştiri, sfenoidal elektrotların faydasını saptayabilecek kadar hasta sayısının olmamasıdır. Daha fazla hasta sayısı ile prospektif çalışma yürütmek hangi hastanın sfenoidal elektrotlardan yararlanabileceğini tanımlamada faydalı olacaktır.*

Anahtar Sözcükler: *Sfenoidal elektrot, dirençli epilepsi, epilepsi cerrahisi.*

Introduction

Among all types of epilepsy, the prevalence of temporal lobe seizure is 30-35%. While 60-70% of partial seizures are associated with the temporal lobe, 2/3 of those are cases of mesial temporal lobe epilepsy (MTLE) (1). 25-30% of epilepsy can not be controlled by medical therapy. One third of this group are candidates of epilepsy surgery (2). Most of the candidates for epilepsy surgery are patients with temporal epilepsy (3, 4). In patients diagnosed with drug-resistant epilepsy whose epileptic focus localization and lateralization couldn't be determined, Phase 2 assessment should start. Phase 2 assessment includes semi-invasive and invasive procedures (5). Scalp electrodes provide beneficial data on epileptic focus localization and lateralization. In some cases, surface anterior temporal electrodes (ATE) fail in determining epileptic discharges originating from the mesial temporal structures (6). Sphenoidal electrode (SpE) placement is a semi-invasive procedure that is used routinely along with anterior temporal electrodes in order to improve temporal lobe EEG recordings in some epilepsy centers. However, basal electrodes should be placed accurately close to foramen ovale (FO) (7). We placed bilateral SpE via fluoroscopic guidance in bitemporal epilepsy patients. The distance of the electrode to the FO was measured by 3D computerized tomography (CT) after the procedure. For the simultaneous recording with SpE and 10/20 system scalp electrodes, T1/T2 surface electrodes were applied. At least 3 clinical seizures were recorded. The efficacy of SpE and ATE are compared by seizure activity parameters, as well as the contribution of proximity to FO and cranial base in evaluating lateralization.

Materials and Methods

Ten patients (5 males and 5 females) with refractory bilateral temporal lobe epilepsy without lateralization via scalp video-EEG were included in the study. The exclusion criteria were as follows: Being below 18 or above 65 years of age, having a systemic infection or a local infection over the related area, displaying abnormal bleeding test results, having psychiatric disorders or mental retardation that would prevent compliance to monitoring process, and being pregnant. Ethics approval was provided by the local ethics committees.

Presurgical and surgical procedures were performed after obtaining the informed consent of the patients.

We placed SpE following the acquisition of appropriate images with fluoroscopy. While the needle was clearly visible by fluoroscopy before its removal, the remaining electrode was less visible due to be a platinum metal. Therefore, after the intervention, we evaluated the contribution of the electrode position to recordings, along with checking the final position of the electrode with 3D CT of the skull base. The ideal electrode placement site is anterolateral of FO (Figure-1). By using the Picture Archive & Communication System (PACS), following measurements were made on images acquired by CT (Figure-2 and Figure-3):

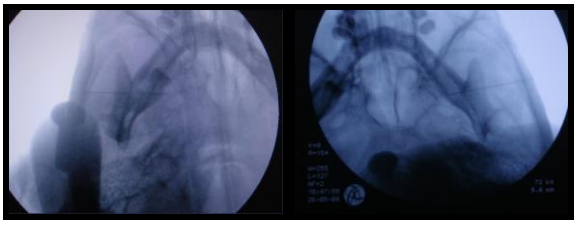

Figure-1. Right and left SpE's localization at fluoroscopic images.

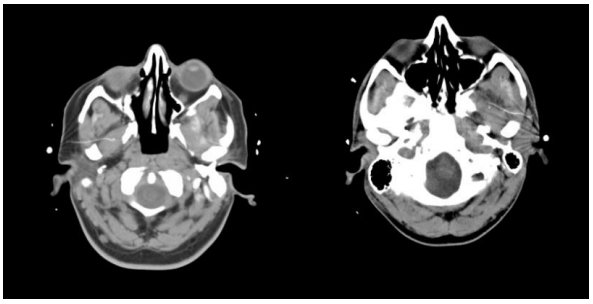

Figure-2. Right and left SpE's position at axial CT image.

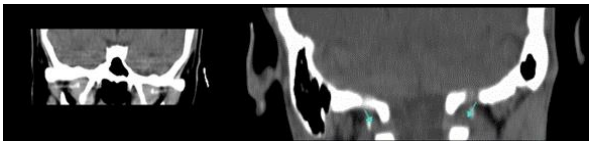

Figure-3. Skull base and FO's proximity to electrodes at coronal CT image.

1. Entry point: The distance between the tragus and the electrode entry point in axial plane (mm).

2. Electrode length: The distance between the electrode entry point and electrode tip in axial and coronal planes (mm).

3. Proximity to the foramen ovale: The distance between the FO outer margin and electrode tip distance in coronal plane (mm).

4. Proximity to the skull base: The distance between the skull base and electrode tip in coronal plane (mm).

Left and right FO-electrode tip distance values were determined as ≥5 mm and <5 mm, respectively. Left and right skull base-electrode distance values were determined as ≥3.5 mm and <3.5 mm. Lateralization results were analyzed based on its proximity to the FO and skull base.

After the CT examination, the patients were transferred to the video-EEG unit. For simultaneous recording, scalp electrodes were placed according to the 10-20 system and T1/T2 anterior temporal electrodes as well. The patients were monitored until the occurrence of at least 3 seizures. All the 20 electrodes provided eligible records. We used following parameters to evaluate the seizure activity recorded by each electrode (SpE and ATE) (Figure-4 and Figure-5).

1. Time of seizure onset

2. The electrode demonstrating the highest amplitude during seizure

3. Earlier onset of seizure in SpE than in ATE (min. 5 second earlier)

4. Higher amplitude or frequency in concurrent seizure onsets

5. In the presence of bilateral activity, the hemisphere with higher amplitude or frequency was recognized as asymmetric.

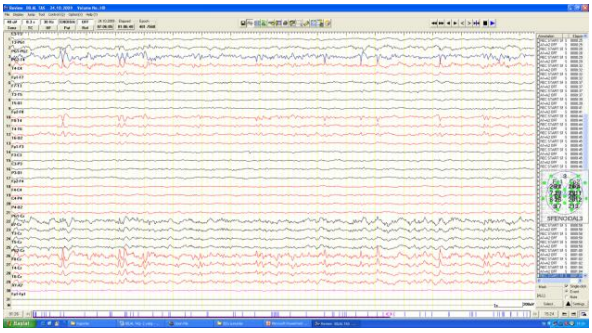

Figure-4. Hight amplitude spike wave at interictal recording of right SpE.

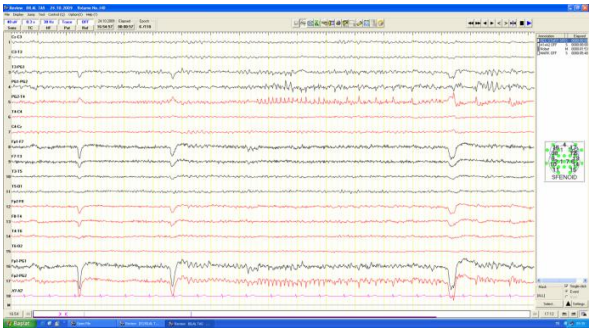

Figure-5. 20 seconds earlier onset of seizure at SpE than ATE.

The cases with unilateral EEG lateralization findings were categorized as the lateralized group and termed as unilateral seizure. The bilateral lateralization findings were categorized as the non-lateralized group and named as bilateral seizure. The cases with bilateral seizure activity despite presence of asymmetric findings between right and left hemispheres were also categorized as bilateral.

The patients in whom we were unable to evaluate the ictal activity in the SpE and ATE due to an artifact, were categorized as the artifacted group. Statistical analysis was performed by using SPSS (Statistical Package for Social Sciences) for Windows 15.0 package program. Pearson Chi-square and Fisher's exact test was used in comparison of statistical analysis of data. Results were evaluated in the confidence interval of 95%, $p<0.05$ was considered statistically significant, $p>0.05$ was considered statistically insignificant.

Results

The mean age of the patients was 30.2 (range: 18-47). All the patients were evaluated with regard to medical and seizure history. The assessment of the magnetic resonance imaging (MRI) findings relative to Phase 1 evaluation showed mesial temporal sclerosis (MTS) in four (40%) patients. MTS was on the left in one case, on the right in one case, and bilateral in two cases. Three cases presented with low grade glioma and one case had dysplasia. Of the three cases with low grade glioma, two had left and one had right mesial temporal lobe localization. Dysplasia was detected in the left temporal lobe. During the placement of electrodes none of the patients developed any complication.

The positron emission tomography (PET) findings and lateralizations revealed that five (50%) of the 10 cases had interictal hypometabolism. The hypometabolism localization was right temporal lobe in two cases, left temporal lobe in two cases, and bilateral temporal lobes in one case.

The mean recording time was 7 days (range: 3-11 days) and the number of recorded seizures was 202. Although all the patients semiologically demonstrated complex partial seizures along with secondary generalized complex partial seizures, the seizure onset can not be clearly differentiated in five (50%) patients by scalp EEG findings. However, electrophysiologically, they were observed to have unilateral or bilateral temporal-frontal seizure activity or diffuse interictal EEG activity. Therefore, temporal-frontal localization and lateralization could not be achieved in these patients. Five (50%) patients displayed bilateral frontal-temporal epileptic activity. Thus, they were deemed as cases of bilateral temporal epileptic activity. However, the onset of the seizures could not be lateralized.

From patient-1, we did not receive an ictal recording. However, it was evaluated to be right-sided due to the presence of high-amplitude sharp and slow waves in the SpE EEG.

In patient-5, a total of 92 seizures were recorded. All the seizures were in the frontal lobe. During the seizures, SpE showed no seizure activity. Patient-6 exhibited only one seizure recording which was located in the frontal lobe. This patient did not show any seizure activity in SpE, as well.

A total of 32 seizure recordings were evaluated. Simultaneously recorded SpE and ATE data revealed that 26 (84.3%) of the 32 seizures exhibited ictal data indicative of anterior temporal seizure activity.

Of the 26 seizures that provided ictal recording data, 12 (46.2%) had bilateral temporal origin and 14 (53.8%) seizures had unilateral temporal origin. Four (15.4%) of the unilateral seizures were right-sided, whereas 10 (38.5%) were left-sided.

Among the ictal recordings obtained from the SpE, 6 (18.8%) of the 32 seizure recordings had an artifact. Nine recordings demonstrated earlier onset and higher amplitude in SpE than in ATE, whereas 17 (53.1%) showed similar findings in SpE and ATE. Of these 17 recordings, 12 were bilateral and 5 were unilateral. A total of 14 seizures, five unilateral seizures and 9 seizures with earlier onset and higher amplitude in the SpE than in the ATE, were lateralized.

Of the 32 seizures, 24 (75.0%) were determined both in the SpE and ATE electrodes. Among these 24 seizures, 9 (28.1) demonstrated earlier onset and higher amplitude in the SpE, as compared to ATE. Six of those nine recordings with earlier onset exhibited earlier seizure activity in the SpE as compared to ATE, with a mean duration of 9.17±4.67 seconds. The remaining three (12.5%) seizure recordings had concurrent onset in both electrodes, whereas SpE amplitude was higher than that of ATE. Among the other five seizures that were unilaterally lateralized, both SpE and ATE showed equivalent findings, however, since the EEG findings were unilateral nature, they were defined as unilateral seizures.

A total of 17 seizures displayed equivalent findings both in the SpE and ATE electrodes. In the SpE recordings, 17 (53.1%) of the 32 seizures showed equivalent findings. In the ATE recordings, this rate was 70.8%. The presence of equivalent findings in the SpE and ATE was statistically significantly higher ($p=0.001$, $p<0.05$). (Table-1).

As compared to ATE, we detected earlier onset and higher amplitude in the SpE in nine (28.1%) of 32 seizures. Among those 9 seizures, 6 (25%) showed earlier seizure activity in SpE than in ATE. The mean duration of early seizure onset was 9.17 ± 4.67 seconds. In all the electrodes with an early seizure activity, the SpE amplitude was higher than the ATE amplitude. The remaining three (12.5%) seizure recordings demonstrated concurrent seizure onset in SpE and ATE, however SpE amplitude was higher than ATE amplitude. Among the 32 seizure recordings, the presence of lateralizing findings (earlier seizure onset and higher amplitude) in 9 recordings in the SpE was statistically significant ($p=0.013$, $p<0.05$).

According to the measurement of 20 electrodes during 3D CT imaging of the skull base; the mean entry point was 28.19±2.84 mm (25-34 mm). The mean electrode lengths on axial and coronal CT images were 43.47±1.69 mm (41.4-47 mm) and 42.61±2.04 mm (40.2-45.7 mm) respectively. The axial electrode length was observed to be greater than that of coronal electrode length. This difference was attributed because the hook like shape of the electrode tip. The mean distance of the electrode tip to the FO and skull base was 4.46±0.82 mm (3.5-5.5 mm) and 3.6±1.22 mm (2-5.5 mm), respectively.

We evaluated the proximity of electrode tip to FO and skull base relative to the lateralization of the seizures. On the right, no statistically significant difference was found in seizure lateralization with regard to proximity to FO ($p<0.05$). However, on the left, the incidence of cases ≥5mm was statistically significantly higher than the incidence of cases <5mm with regard to proximity to FO in patients with bilateral seizure lateralization ($p=0.021$, $p<0.05$).

On the right, there was no statistically significant difference between the groups with regard to distance between the skull base and the electrode ($p>0.05$). However, left-sided and bilateral seizure frequency found statistically higher where the skull base-electrode distance is lower than 3.5 mm ($p=0.001$, $p<0.05$) (Table-2).

We investigated the unilateral group with regard to any difference between the right and left sides in terms of proximity to FO and skull base. Seizure lateralization and proximity to FO didn't show statistically significant correlation with regard to left-sided or right-sided seizure incidences ($p>0.05$).

Table-1. Lateralization distribution of SpE to ATE findings.

		ATE				Total			p
		Artifacted		Equivalent finding					
		n	%	n	%	n	%	n	
SpE	Artifacted	6	75.0%	0	0.0%	6	18.8%	0	
	Equivalent finding	0	0.0%	17	70.8%	17	53.1%	1	
	Earlier onset and higher amplitude at SpE to ATE	**2**	**25.0%**	**7**	**29.2%**	**9**	**28.1%**	**0**	**0.001***
	Total	8	100.0%	24	100.0%	32	100.0%	1	

**Pearson Chi-Square*

Table-2. Proximity to FO according to seizure lateralization and the distribution of distance between SpE and skull base.

		Lateralization								
		Right		Left		Bilateral		Total		
		n	%	n	%	n	%	n	%	p
FO distance Right	<5mm	2	50.0	5	50.0	6	50.0	13	50.0	1.000*
	>=5mm	2	50.0	5	50.0	6	50.0	13	50.0	
FO distance Left	<5mm	1	25.0	5	50.0	0	0.0	6	23.1	**0.021***
	>=5mm	3	75.0	5	50.0	12	100.0	20	76.9	
Distance between skull base and SpE - Right	>3,5mm	2	50.0	9	90.0	11	91.7	22	84.6	0.113*
	<3,5mm	2	50.0	1	10.0	1	8.3	4	15.4	
Distance between skull base and SpE - Left	>3,5mm	3	75.0	1	10.0	12	100.0	16	61.5	**0.001***
	<3,5mm	1	25.0	9	90.0	0	0.0	10	18.5	

**Fisher's exact test*

There was no statistically significant intergroup difference at right-sided seizures in terms of skull base-electrode distance (p>0.05). However, left-sided seizure incidence was statistically significantly higher in cases with skull base-electrode distance less than 3.5 mm (p=0.041, p<0.05).

We compared SpE lateralization results with MRI, PET, SCALP EEG lateralization. According to SpE lateralization statistically significant difference is found between MRI results (p<0.05). According to SpE lateralization statistically significant difference isn't found between PET CT and Scalp EEG results (p> 0.05) (Table-3).

Table-3. Comparison of MRI, PET, SCALP EEG lateralization results with SpE lateralization.

		SpE lateralization								
		Right		**Left**		**Bilateral**		**Total**		
		n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**p**
MRI	Right	2	100					2	25	
	Left			2	100	2	50	4	50	**0.040**
	Bilateral					2	50	2	25	
PET	Right					1	25	1	13	
	Left					2	50	2	25	0.308
	Normal	2	100	2	100	1	25	5	63	
Scalp EEG	Bilateral	1	50	1	50	3	75	5	63	
	Not clear seizure onset	1	50	1	50	1	25	3	38	0.766

In conclusion, according to the findings obtained from SpE recordings, seizures were lateralized as right-sided in 2 patients and left-sided in 2 patients, whereas 4 cases were deemed as bilateral.

Discussion

Sphenoidal electrodes were first described by Jasper in 1949 in order to improve the temporal lobe EEG recordings (8). In 1951, D.P. Jones defined the lateral approach. He described the "anterior sphenoidal" electrode and explained that the electrode could be placed close to the FO and EEG recording could be obtained from the coronal plane (9). In 1977, Ives and Glor developed multicoil wires that could be inserted through the needle (10). In 1989, Sperling and Engel defined the "standard blind technique" that is still in use today (11).

There are strong motives concerning the use of SpE. The increasing need to determine interictal spikes has accelerated the development of SpE. Interictal EEG detects focal spike or sharp waves in 30% of recordings, and according to some studies, at least 50-60% of the recordings have been detected during sleep. SpE demonstrates an efficacy of nearly 90% (12).

The spread of hippocampal discharges to the lateral cortex due to sequential activation of the basal temporal lobe may lead to its detection by the scalp electrodes. However, if the discharges and seizures remain limited and do not spread to the adjacent cortex, these discharges can not be detected by the surface electrodes. In order to catch such limited discharges, basal electrodes should be placed. The proximity of SpE to the FO, increase their sensitivity. The absence of an interposed bone during EEG recording allows higher efficacy (13).

In the standard international 10/20 system, F7 and F8 electrodes are the closest to the temporal lobe during scalp placement, whereas they are still relatively distant to the mesial temporal cortex (14). The closer SpE is placed to the temporal cortex, the higher interictal spike amplitude is observed. Spike amplitudes are 10-20% higher as compared to cheek electrodes, with a signal rate of %16.5 (15). Various studies comparing the SpE with others simultaneously have been conducted. It has been compared with scalp, deep, nasopharyngeal, nasoethmoidal, and ear electrode recordings (13, 16, 17, 18). SpE are reported to detect interictal spikes more

commonly than other electrodes. Ictal studies using SpE report higher seizure detection rates. Seizures have been found to appear earlier in SpE than in scalp electrodes.

Although Kanner et al. have highlighted the benefits of SpE in 1950s, the number of studies with fluroscopy is rare in literature (19).

In many centers, SpE is placed over the infratemporal fossa with varying distance to FO, in a blind fashion without fluoroscopy, and the verification is done by submentovertex projection. The easily applicable technique by bedside may be the reason underlying the popularity of blind method in epilepsy centers. Also habits and using directions of fluoroscopy may be the other reasons. Currently visual guidance should be preferred in the minimally invasive procedures.

SpE placed in a blind fashion have been noted to fail in detecting anterior-mesial-temporal seizure foci on EEG recordings, while SpE placed via fluroscopy has been shown to detect seizure foci in 53% of the electrodes (19). Moreover, SpE placement under visual guidance is more reliable, since it reduces the risk of damaging middle meningeal artery and trigeminal nevre (19, 20) In another study, 40 patients received SpE placement via fluoroscopy, the results showed that fluoroscopic guidance presents significant advantages as compared to blind placement, leading to a higher sensitivity in detecting mesial-basal-temporal lobe epileptic activity by allowing closer electrode placement to the target location and causing less facial pain (21).

During SpE recording, temporary venous hemorrhage and pain-related vagal snycope is commonly seen, while salivary gland penetration, arterial hemorrhage, and nerve damage are noted as rare complications (18, 22). In conclusion, the use of fluoroscopy reduces potential complications such as vascular and nerve damage, while enabling electrode insertion as close as possible to the FO (18).

SpE placement is deemed as a safe procedure with only minor complications such as mild bleeding, pain, swelling, temporary facial paralysis and convulsive syncope. There are authors who report vagal syncope and convulsive syncope during blind electrode placement. The autonomic response leading to syncope and paralysis has been associated with direct stimulation of the trigeminal nerve and the fear caused by the pain and/or procedure (22). Temporary facial paralysis has been observed to occur due to local anesthetic use (23). There are studies indicating that local anesthetic use is not necessary, since the pain induced by the needle used for local anesthetic delivery is regarded as equivalent (11, 24). Our procedure was applied under sedation, so the risk of facial paralysis didn't ocur and eliminated the risk of vagal syncope. None of our patients developed pain, intolerance to the procedure, and complications.

The expected place of the electrode tip was verified by axial, coronal, and sagittal skull base CT imaging. In Luder's 17 patient study the positions of SpE were taken with two orthogonal x-rays and a computer program was used to find the locations of the tip of the needle (25).

Although we observed the influence of proximity to skull base on lateralization, there is need for further studies including larger samples for verification. In the present study, sphenoidal electrodes succeeded in lateralizing 9 (28.1%) of the 32 episodes. Among the lateralized episodes, 6 (18.7%), 6 (18.7%) had early episode onset. The mean time of early episode onset detection was 9.1 s. Although 3 episodes exhibited simultaneous onset in the SpE and ATE, the SpE amplitude was higher than that of ATE. In our study, the efficacy of sphenoidal electrode was 28.1%.

Conclusion

Fluoroscopy allowed sensitive placement of the SpE in our study. In order to perform a more effective lateralization on SpE recordings, the electrode should be inserted close to both FO and skull base. It's a safe method, avoids complications and easy to apply.

Using 3D CT for final position assessment of the electrode is widely available method. It enables us to evaluate the proximity of the electrode to FO and skull base,

Although the additional contribution of SpE appears small, a utility of 5-10% is regarded as a considerable contribution. Moreover, for some patients, these data are considerably valuable. If the SpE suffices without the need for an intracranial electrode insertion, then minor inconveniences induced by the insertion can be ignored.

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