Introducing the Posterior Condylar Emissary Vein as an Effective Surgical Landmark for Optimizing the Standard Retrosigmoid Approach: An Anatomo-Imaging Study

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■ OBJECTIVE: **There is a lack of definite anatomical landmarks for the inferior extension of the standard retrosigmoid approach. In this study, we evaluated whether the posterior condylar emissary vein (PCEV) can be used as an intraoperative landmark for optimizing the surgical corridor.**

■ METHODS: **We performed the standard retrosigmoid approach on 5 formalin-fixed and latex-injected cadaveric specimens and measured the distance between the PCEV near its bony canal and the vertebral artery (VA). In addition, vascular reconstructions of thin-sliced preoperative computed tomography (CT) scans were studied in 40 patients and the relationship between these 2 vessels was evaluated. An illustrative case is also included.**

■ RESULTS: **The PCEV was consistently identified on both sides of cadaveric specimens and in 87.5% and 82.5% of the left and right sides of the included CT scans, respectively. The average distance between the part of the PCEV near its osseous canal and the VA was measured to be between 8.4 mm and 8.6 mm in the specimens and between 9.2 mm and 9.3 mm in the CT scans. This distance offers a safe and effective plane of dissection during the standard retrosigmoid approach and allows easy access to the foramen magnum.**

■ CONCLUSIONS: **The PCEV near its bony canal proved to be an easy, straightforward, safe, and effective operative landmark with which the surgeon can extend the soft tissue dissection and bony exposure towards the foramen magnum. This maneuver provides ample access to the cisterna magna for cerebrospinal fluid drainage and increases visibility and surgical maneuverability to the entire cerebellopontine angle.**

INTRODUCTION

The retrosigmoid approach is considered a workhorse in postero-lateral skull base surgery, being ideal for addressing lesions located in and around the cerebellopontine (CP) angle. Since its first description by Krause, numerous modifications have been proposed with regard to skin incision, soft tissue dissection, and craniotomy dimensions.[1-5] Traditionally, the skin incision is straight within the hairline and extends roughly one-third above and two-thirds below the root of the mastoid, followed by a stepwise soft tissue dissection.[6] Craniotomy-wise, however, the current skull base literature mainly focuses on the relative indications of extending the superolateral limit of bone removal towards the venous sinuses, in contrast to the caudal limit, which has not been standardized and is usually adjusted to the characteristics of the pathology and the surgeon's preference.[1,4,5] The lack of definite anatomical

Key words
- Cranial approaches
- CP angle
- Emissary vein
- PCEV
- Posterior fossa
- Retrosigmoid
- Skull base

Abbreviations and Acronyms
CP: Cerebellopontine
CSF: Cerebrospinal fluid
CT: Computed tomography
IO: Inferior oblique
PCC: Posterior condylar canal
PCEV: Posterior condylar emissary vein
RCPM: Posterior rectus capitis major
RCPm: Posterior rectus capitis minor
SO: Superior oblique
VA: Vertebral artery

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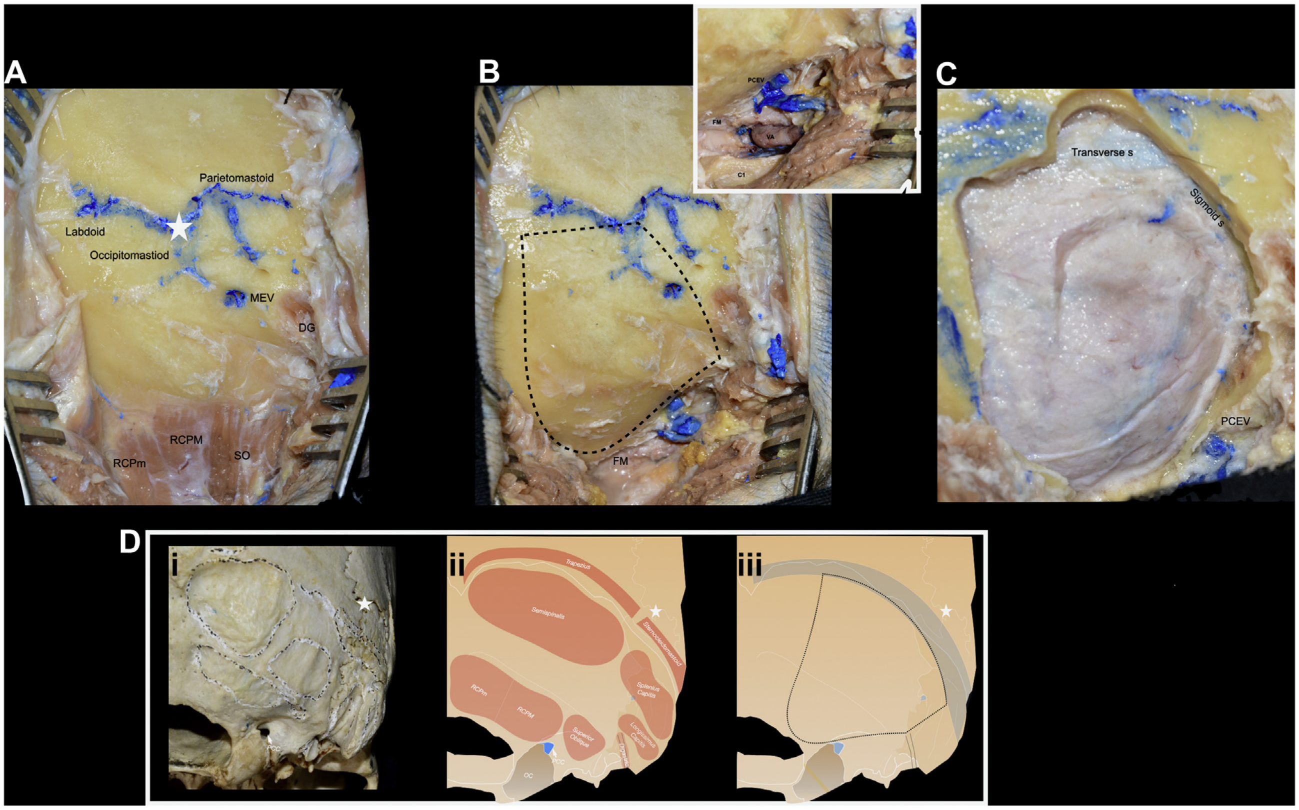

Figure 1. Cadaveric dissection. (**A**) Standard right-sided retrosigmoid approach. The superficial muscle layers have been dissected and elevated from the superior nuchal line, revealing the cranial sutures forming the asterion (*white star*) (lambdoid, occipito-mastoid, and the parieto-mastoid sutures respectively). The deep muscle layer is recognized at the lower part of the incision. The superior oblique (SO) and the rectus capitis posterior major (RCPM) muscles form the apex of the suboccipital triangle. Note the digastric groove (DG) below the root of the mastoid process, in which the posterior belly of the digastric muscle resides and which serves as the lateral limit of muscle dissection. (**B**) Dissection of the deep muscles reveals the PCEV and the contents of the suboccipital triangle. The dashed line delineates the craniotomy planned. Using the PCEV as a surgical landmark the craniotomy can extend close to the foramen magnum (FM). The inlet shows the spatial relationship between the PCEV and the VA near the FM. (**C**) The Retrosigmoid craniotomy as planned in Figure 1B. The upper and lateral limits are the transverse and the sigmoid sinuses respectively, while the inferior limit extends near the FM, as approximated by the position of the PCEV. (**Di**) Human skull, right side. The position of the PCC is indicated with the white arrow at the posterior apex of the condyle. (**Dii**) Representation of the bony attachment of the spinocervical and suboccipital muscles. (**Diii**) The Retrosigmoid craniotomy delineated by the dotted line. The hypoglossal canal is shown in yellow, crossing the condyle. (FM, foramen magnum; DG, digastric groove; MEV, mastoid emissary vein; OC, occipital condyle; PCC, posterior condylar canal; PCEV, posterior condylar emissary vein; RCPM, rectus capitis posterior major; RCPm, rectus capitis posterior minor; SO, superior oblique).

landmarks to guide a safe, effective, and replicable inferior extension of the approach allows for surgical routine and surgical confidence to fill this gap of knowledge and can potentially compromise operative maneuverability and consequently affect surgical outcomes.

The posterior condylar emissary vein (PCEV) is a consistent anatomical entity of the region. It connects the jugular bulb to the venous complex surrounding the vertebral artery (VA), also known in the literature as the posterior cavernous sinus due to its rich vascularity. It exits the cranial vault through the posterior condylar canal (PCC), which is located superior to the hypoglossal canal, just above the condyle. Less common drainage sites are the sigmoid sinus and the occipital sinus.[7-12] The vessel's size varies from 1 to 10 mm (mean: 3.4—6.3) and makes it easily recognizable in the majority of imaging modalities as well as intraoperatively.[11,13-18] The constant spatial relationships of the PCEV with regard to the hypoglossal canal, the occipital condyle, the mastoid, the lateral part of the foramen magnum, and the jugular bulb could potentially make it an ideal reference surgical landmark for postero-lateral skull base corridors, and particularly for optimizing the retrosigmoid avenue.

With this in mind, we set out to investigate the applicability of using the PCEV as a reliable anatomical landmark in the quest to standardize a safe inferior soft tissue dissection and an effective bony removal during the retrosigmoid approach. We have to stress that in our skull base practice we have customarily been using the PCEV as a guide for the inferior limit of our dissection but without robust anatomical evidence and only out of surgical habit.

METHODS

To demonstrate the applicability of the PCEV as an effective surgical landmark, we applied a multimodal approach. First,

Table 1. Summary of the Measurements in Computed Tomography of Patients and Cadaveric Specimens, of the Minimum Distance Between the Posterior Condylar Emissary Vein and the Vertebral Artery

Side	Measured (No pts)	N/	% PCEV Identified	Mean Distance (mm)	Range (mm)
CT R	40	7	82.5	9.3	4.3—13.3
CT L	40	5	87.5	9.2	5.5—12.4
C R	5	0	100	8.6	7—10
C L	5	0	100	8.4	7.5—9.5

The frequency of the PCEV identification is reported for each side and is consistent with current literature.

C, cadaveric; CT, computed tomography; R, right; L, left; pts, patients; N/A, vessel not identified; PCEV, posterior condylar emissary vein; VA, vertebral artery.

we performed cadaveric dissections in the microneurosurgery laboratory and meticulously recorded our findings. We then studied contrast-enhanced, thin-sliced computed tomography (CT) scans of randomly selected patients from our database. Finally, we recorded an illustrative case, where the PCEV was clearly recognized and used as the inferiormost limit of our soft-tissue dissection as per our routine surgical practice.

Cadaveric Dissections
We performed stepwise meticulous soft tissue dissections during a standard retrosigmoid approach on both sides of 5 cadaveric formalin-fixed, color-latex injected heads, thus totaling 10 sides. The spatial relationship between the PCEV and the VA as well as the extent of the craniotomy performed were recorded. Measurements of the relative distances were taken with a standard surgical ruler. As in all cadaveric studies, the measurements recorded serve as an estimate when compared with real operative settings and convey the basic spatial relationships of the relevant anatomical entities.

CT Measurements
We studied the vascular reconstructions on thin-sliced contrast-enhanced CT scans (1 mm or less) of 40 patients. The distance between various points among the 2 vessels (PCEV and VA) were measured both in the coronal and sagittal plane and the one that was selected as more relevant was that between the superior wall of the PCEV near its bony canal and the superior wall of the VA at their closest point.

Ethics
Informed Consent. This is a cadaveric study. All cadaveric specimens used in the current study were obtained by the providing company after strict self-consent or consent from the legally authorized representatives or next of kin of the donors.

Consent for Publication. All patient data used in this study are fully anonymized and no identifiable protected health information are included. Nevertheless, an informed consent was obtained from the patients.

RESULTS

Skull Base Dissections
A straight skin incision, similar to the one used in a standard retrosigmoid approach, was fashioned and followed by a stepwise soft tissue dissection. The superficial muscle layers formed by the trapezius, sternocleidomastoid, splenius capitis, and semispinalis capitis muscles were recognized, divided with a scalpel along the incision, and detached from their bony insertion. Lateral mobilization of these muscles aids in the exposure of the mastoid process up to the root of the digastric groove and exposes the lambdoid, occipito-mastoid, and parieto-mastoid sutures forming the asterion along with the mastoid emissary vein and its foramen. The deep muscle layer consisting of the superior oblique (SO), inferior oblique (IO), posterior rectus capitis major and minor (RCPM and RCPm, respectively) is identified and after detaching and elevating the SO muscle we encounter the PCEV entering the suboccipital triangle towards its foramen.

The PCEV was consistently found in close proximity to the suboccipital triangle and the VA. The distance measured between the most superior part of the PCEV wall near its entrance in the bony canal and the most superior part of the VA wall was approximately 8.8 mm (range: 10—7 mm) on the left side and 8.5 mm (range: 9.5—7.5 mm) on the right side. A standard retrosigmoid craniotomy could be then turned down to the level of the PCEV, providing effective access to the foramen magnum, cisterna magna (via the cerebello-medullary cistern), and the entire CP angle (**Figure 1**).

CT Measurements
Table 1 shows the PCEV—VA distance as this was measured in the preoperative scans. The PCEV could be clearly identified in 82.5% on the right-side scans and in 87.5% on the left-side scans. The mean distance from the most superior part of the PCEV wall near its entrance in the bony canal to the most superior part of the VA wall was 9.3 mm on the right side and 9.2 mm on the left side (**Figure 2**).

Illustrative Case
A 42-year-old female patient underwent a retrosigmoid craniotomy for an epidermoid tumor on the left CP angle, extending along the ventrolateral surface of the brainstem, from the tentorial incisura down to the foramen magnum.

A straight skin incision was fashioned, followed by stepwise muscle dissection and subperiosteal elevation. At the level of the inferior nuchal line, elevation of the SO muscle revealed the PCEV. This vessel is of considerable caliber and easily recognized intraoperatively, therefore serving as the most inferior and lateral limit of the soft tissue dissection and bony exposure for subsequent drilling (**Figure 3**). In this way easy access to the foramen magnum, cisterna magna, and CP angle is granted.

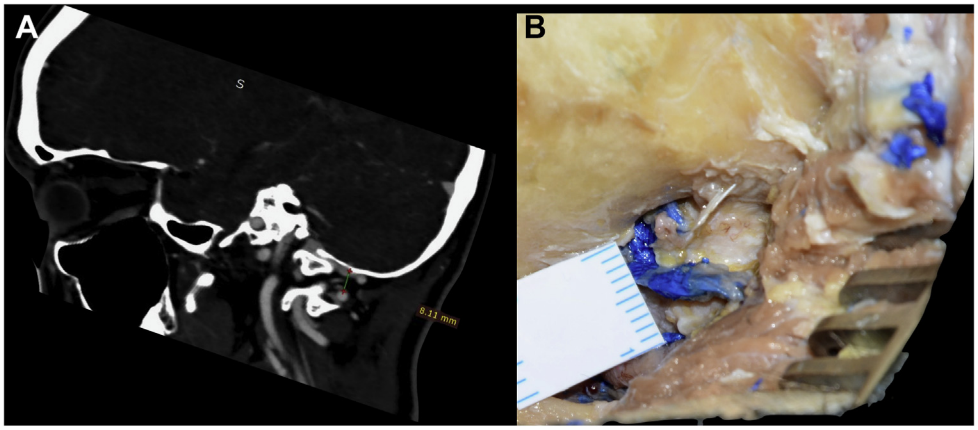

Figure 2. Measurement of the minimum distance between the PCEV and the VA. The distance between the superior wall of the PCEV near its bony canal and the superior wall of the VA is shown. (**A**) CT measurement. (**B**) Cadaveric measurement.

DISCUSSION

Our aim was to study the utility and applicability of the PCEV as a surgical landmark for a safe and effective inferolateral soft tissue dissection and subsequent bony removal during a standard retrosigmoid approach. To this end we performed stepwise cadaveric dissections and CT scan measurements to test our hypothesis. We also include an illustrative case, since we have been using this landmark in our skull base routine for a long time but only out of surgical habit and intuition.

During the cadaveric skull base SO muscle. The dissection was continued until the VA was revealed and the average distance measured between these vessels (8.8 mm and 8.5 mm) proved to offer a safe operative plane. A craniotomy extending down to the point where the PCEV enters its foramen was fashioned, followed by bone drilling just to expose the beginning of the sigmoid and transverse sinuses and then the dura was opened to enter the CP angle. In this way the bony window comes down to the foramen magnum in an easy and effective way and provides ample access to the cisterna magna for cerebrospinal fluid (CSF) drainage and a wide surgical corridor to the entire CP angle.

With regard to the CT scan measurements, identification of the PCEV was possible in 82.5% on the right-side scans and in 875% on the left-side scans, a percentage that is consistent with the current literature.[10,11,13,16-21] Intraoperative recognition of the PCEV is possible in more than 40% of cases where it was not evident in the preoperative imaging.[9] In certain reports, the PCEV is more often recognized in the left side, although in our study no such difference was observed.[18] We found the average distance of the PCEV from the VA to be 9.3 mm on the right side and 9.2 mm on the left side, which, to the best of our knowledge, has not been previously reported in the literature.

Introducing the PCEV as a Novel Surgical Landmark During the Retrosigmoid Approach

One of the basic tenets of skull base surgery is to obtain early access to the basal cisterns for adequate CSF drainage with the aim to aid brain relaxation, increase surgical maneuverability, and ensure a better dissection plane. With regard to the retrosigmoid corridor, premature sharp opening of the cerebellomedullary cistern leading to the thick arachnoid membrane of the cisterna magna relaxes impressively the cerebellum and allows for better visualization, navigation, and dissection around the neurovascular structures of the CP angle.[1,3,5,7] To this end, exposure of the superolateral part of the foramen magnum followed by a slight caudal extension—towards the foramen—of the usual retrosigmoid osseous window achieves this surgical goal.

However, as the soft tissue dissection moves downwards, the surgeon becomes increasingly vigilant, careful and anxious so as not to accidentally enter the suboccipital triangle and inadvertently injure the vertebral artery. This concern usually prevents an effective exposure of the inferior part of the occipital bone, which in turn limits the craniotomy and obstructs the view and surgical manipulation of the cisterna magna. In an effort to reduce this concern and maximize the exposure achieved, we propose using the PCEV as a reliable operative landmark for the safe inferior extension of the soft tissue dissection and bony removal. The part of the PCEV near its canal (PCC) is used as a guide for the different modifications of the far lateral approach (transcondylar, transjugular, etc.[9-11,22,23]) but has never been proposed and utilized as a surgical landmark for the retrosigmoid corridor.

Identifying the PCEV near its canal is quite straightforward and easy because it is a prominent and constantly present vein, encountered just after detaching the superior oblique muscle, as the soft tissue dissection proceeds downwards. The distance measured between the PCEV and VA offers a safe intraoperative plane of dissection safeguarding the VA, as it is connected to the superoposterior part of the suboccipital cavernous sinus surrounding the VA.[17] The only exception, in rare cases, is the presence of a high-riding VA and/or extracranial posterior inferior cerebellar artery, which can be identified in the preoperative scan. Lastly, accidental perforation and injury of the vein has been infrequently linked with major complications,[8] unless there is an underlying genetic disorder, such as achondroplasia,[20] or a

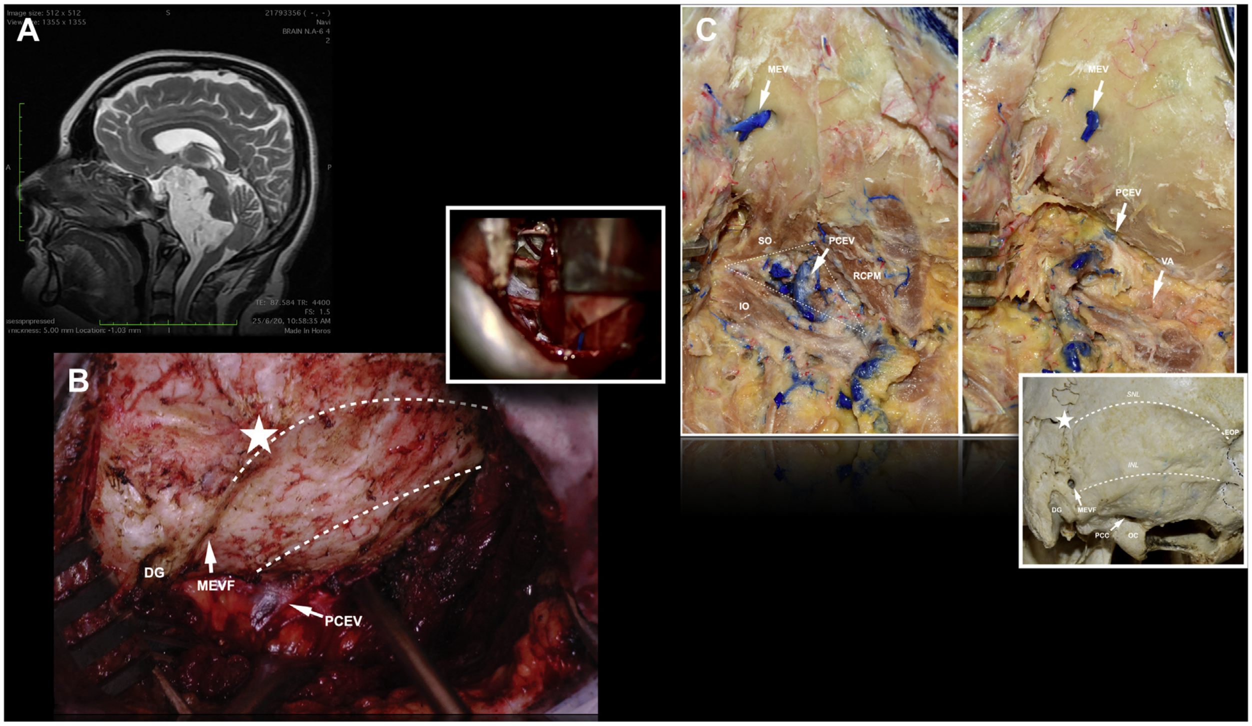

Figure 3. (**A**) Preoperative MRI scan (sagittal cut through the midline) of a 43-year-old patient with an extended epidermoid tumor of the left CP angle. The caudal extension of the tumor, to the foramen magnum, is evident in this image. (**B**) Intraoperative photo of the same patient undergoing a left retrosigmoid craniotomy. After the standard soft tissue dissection, the PCEV can be clearly identified and preserved at the inferior limit of muscle dissection. The suction points to the foramen magnum (FM). The *parallel dashed lines* illustrate the superior and inferior nuchal lines. The *star* marks the asterion, where the burr-hole is drilled. The digastric groove (DG) is recognized at the lateral limit of the soft tissue dissection, with the mastoid emissary vein foramen (MEVF) lying medially. The inlet shows the view through the microscope, emphasizing the extent of the craniotomy. All 3 neurovascular complexes of the CP angle can be easily identified by dynamically retracting the cerebellum. (**C**) Left-side cadaveric dissection, resembling the intraoperative soft tissue dissection. The first stage shows the relative position of the PCEV to the suboccipital triangle (delineated with a *white dotted line*). In the second stage, the muscles of the triangle have been removed, exposing the VA covered by soft areolar tissue. The inlet shows a posterior view of a dry skull, portraying all the bony landmarks identified through this approach. (DG, digastric groove; EOP, external occipital protuberance; INL, inferior nuchal line; IO, inferior oblique; MEV, mastoid emissary vein; MEVF, mastoid emissary vein foramen; OC, occipital condyle; PCC, posterior condylar canal; PCEV, posterior condylar emissary vein; RCPM, rectus capitis posterior major; RCPm, rectus capitis posterior minor; SO, Superior oblique; SNL, superior nuchal line; VA, vertebral artery).

vascular malformation (dural arterio-venous fistula).[24,25] Use of bipolar coagulation, suturing or a venous patch, controls the hemorrhage effectively, whereas hemostasis using bone wax may rarely result in sigmoid sinus wax embolism.[8,9] Hence, the part of the PCEV near its osseous canal proves to be a constant, easy, safe, and effective intraoperative landmark for optimizing the surgical corridor offered through the standard retrosigmoid approach without extending the skin incision or deepening the routine soft tissue dissection.

CONCLUSIONS

The PCEV is a vessel that can be easily recognized, preoperatively and intraoperatively, and exhibits a consistent anatomical relationship with its neighboring structures. Our study provides sound evidence that it could be used as a valuable surgical landmark and guide in the soft tissue dissection and bone drilling during the retrosigmoid approach.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Christos Koutsarnakis: Conceptualization, Methodology, Acquisition of Data, Formal analysis, Data curation, Writing – original draft, Reviewed submitted version of manuscript, Supervision. **Evangelos Drosos:** Acquisition of Data, Formal analysis, Data curation, Writing – original draft, Reviewed submitted version of manuscript. **Spyridon Komaitis:** Acquisition of Data, Formal analysis, Data curation, Writing – review & editing, Reviewed submitted version of manuscript. **Nektarios Mazarakis:** Formal analysis, Data curation, Writing – review & editing, Reviewed submitted version of manuscript. **Eleftherios Neromyliotis:** Writing – review & editing, Reviewed submitted version of manuscript. **Aristotelis Kalyvas:** Formal analysis, Data curation, Writing – review & editing, Reviewed submitted version of manuscript. **Theodore Troupis:** Formal analysis, Data curation, Writing – review & editing, Reviewed submitted version of manuscript. **George Stranjalis:** Formal analysis, Data curation, Writing – review & editing, Reviewed submitted version of manuscript, Administrative/technical/material support.

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