THE EUROPEAN ASSOCIATION
OF NEUROSURGICAL SOCIETIES

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EANS RESEARCH FUND 2022

APPLICATION FORM

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Note: this form should be completed using a font no smaller than 11-point Calibri
Please adhere to the page limits. Only information submitted within these limits can be assessed.
Neurosurgical specialties: please tick the specialty of the project

- ☐ CNS injury
- ☐ Neuro-oncology
- ☐ Vascular
- ☐ Spine
- ☐ Cerebrospinal fluid disorders
- ☐ Paediatrics
- ☐ Functional
- ☐ Peripheral nerve
- ☐ Basic neuroscience

X Operative neurosurgery

☐ Radiosurgery

X Other topics related to neurosurgery

1. PROPOSAL SUMMARY	
Host Organisation:	1) Department of Neurosurgery, Acibadem CityClinic University Hospital Tokuda, Sofia, Bulgaria 2) Department of Radiology Acibadem CityClinic University Hospital Tokuda 3) Department of Neurosurgery, University Hospital of Düsseldorf, Heinrich Heine University, Düsseldorf, Germany 4) Department of Anatomy and Histology, Pathology and Forensic medicine, University Hospital Lozenec, Medical Faculty, Sofia University, Sofia, Bulgaria
Project Title:	Three Dimensional Photorealistic Atlas of Neurological Surgery
Start date & Duration:	**January 2022-December 2022**
PRINCIPAL APPLICANT	

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Date of Birth:	25.November.1984
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Time to be spent on project:	One Year
Signature:	
Date of Signature	
PROPOSAL SUMMARY	
Title:	Three Dimensional Photorealistic Atlas of Neurological Surgery
Lay Abstract *(Please provide no more than half a page)*	
One of the main problems encountered when studying anatomy from traditional 2-dimensional (D) atlases is that one cannot understand easily the complex 3-dimensional (3D) relationships of the soft tissue layers, neurovascular anatomy and bone anatomy from photographs presented from one or multiple angles. These 3D anatomical relationships can change with alteration of	

angle of view when the head is rotated. Therefore, the surgeon must spend endless hours staring at 2D dissection atlas images from different angles in order to reconstruct in his/her mind the spatial 3D anatomical relationships of each critical structure – the course of the vessels and nerves within different fascial planes, individual muscle course and attachments, the depth of the compact and cancellous bone drilling needed to reach target structures (e.g. temporal bone drilling, exposure of sigmoid sinus, middle ear structures, anterior clinoid process drilling for decompression of optic nerve, opening of the internal acoustic canal etc.). In addition to anatomical atlas studies understanding neurosurgical anatomy requires some cadaver dissection experience, which becomes more and more difficult especially in the recent COVID era.
With the advances of modern computer technology allowing the creation of photorealistic 3D models that can be viewed from any desktop and mobile device or presented in augmented reality (AR) and virtual reality (VR) form, opens the field for new possibilities for education in neurosurgery that are now emerging. In particular, technology such as photogrammetry and powerful open-source software packages such as Horos (https://horosproject.org), Slicer (https://www.slicer.org) radiology imaging software with 3D volumetric rendering and 3D modeling features, as well as another open source program - Blender (https://www.blender.org) which is 3D computer graphics software toolset used for creating animated films, visual effects, art, 3D printed models, motion graphics, interactive 3D applications, virtual reality, can make generation and processing of 3D photorealistic anatomical models more comprehensible. Another advance in technology in the form of Internet 3D viewers based on the WebGL and WebXR technologies that allows users to display 3D models on the web, that can be displayed on any mobile browser ad in form of AR, desktop browser or VR headset makes a project for development of a 3D Atlas of Neurological Surgery possible and timely initiative.

Scientific Summary
(Please provide no more than half a page)

In 3D graphics one of the most difficult tasks is to achieve photorealism of the models, which requires complex software and hardware processing in order to create realistic texturing. Moreover, apart from color map and pattern of the 3D model textures there are number of other technical properties of the material that the 3D model is created and how this model interact with the environment, (mainly light) that can change the perception of the model. All these factors make difficult to create photorealistic anatomical model, without deep knowledge of 3D graphic processing, the methods of creation of textures, topology, 3D modeling and sculpting at the cost of very high hardware processing power.
The other problem with 3D graphic based anatomical atlases is that despite the aim of precision when modeling anatomical organs, the models become very stylized and cannot replace the real anatomical image.
In recent years there is another method that evades the complex 3D processing required to achieve photorealistic presentation of the models, which is slowly gaining popularity in the field of neurosurgery [1-4]. A recent search in Pubmed shows only 68 results in relation to photogrammetry and neurosurgery with increase in publications in the recent 8 years (**Fig. 1**). This is a scanning

technique that utilizes macroscopic capture tools such as a professional camera for generation of volumetric 3D data. After the photographs are taken a computer algorhytm obtains information about physical objects and the environment through the process which the metrics of common surface points are extracted from photos to create clouds of colorized coordinates that will subsequently be triangulated allowing the extraction of three-dimensional measurements from two-dimensional data [5, 6]. In other words, photogrammetry facilitates the derivation of 3D information from photographs [5, 6]. This technology is widely used in geography in order to generate a 3D landscape from low attitude aerial photographs or satellite images (e.g. Google maps). Another application of this technology is in archeology to 3D map excavations or create 3D spatial reconstruction of historical monuments. Neurosurgery is relatively new application of this technology, mainly used to present complex anatomy in 3D for the purpose of education and training [6, 7]. However, such technology facilitates greatly the creation of photorealistic anatomical 3D models that require much less 3D processing and modelling.

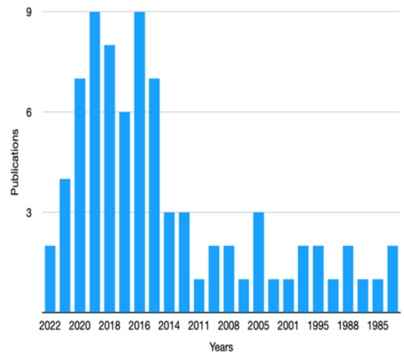

Figure 1. Photogrammetry publications in neurosurgery (Source - *Pubmed: https://pubmed.ncbi.nlm.nih.gov*

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3. Rodriguez Rubio, R., et al., *Immersive Surgical Anatomy of the Retrosigmoid Approach.* Cureus, 2021. **13**(6): p. e16068.
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7. Nicolosi, F. and G. Spena, *Three-Dimensional Virtual Intraoperative Reconstruction: A Novel Method to Explore a Virtual Neurosurgical Field.* World Neurosurg, 2020. **137**: p. e189-e193.

2. PROJECT DETAILS

Background and Scientific Rationale:
(Please provide no more than one page)

The use of 3D anatomical models to teach and describe complex anatomical structures and their relationships has long history in neurosurgery. There are three main methods to generate such 3D models – 1) DICOMs based 3D volumetric models 2) structured-light scanning, or 3) photogrammetry. [1-5]
Programs such Horos, Slicer, Amira are used to create such 3D models and this method has long been used in neurosurgical education, training and preoperative planning. [1-4] The basic technique for constructing a such model is segmentation, which refers to the process of delineating an anatomical structure from a radiographic image (CT or MR image, etc.) [6]. This process can be automated trough program algorhytms or manualy, which is more common and can allow presentation of specific anatomical region of interest or structure (selected vessels, skull stripping etc.)
The other method such as structured-light scanning uses a specialized light scanner to generate the 3D model and can give a very precise volumetric replica of the area of interest. However, the quality of the textures of the 3D models is not sufficient to delineate fine details or complex anatomical structures.
On the other hand, photogrammetry is a method that yields optimal texture quality, due to the fact that it generates the 3D models from 2D photographs. If these photographs are captured using modern high megapixel camera and post processed accordingly the result can be a photorealistic 3D anatomical model. [5, 7]
There are various display format used to visualize these 3D volumetric models including monoscopic, stereoscopic, and mixed reality visualizations – AR and VR [6, 8-14].
Monoscopic displays incorporate virtual anatomical models that are rotated in three dimensions but are presented on a two-dimensional screen, which is the most common way to visualize volumetric 3D models [1-5].
Stereoscopic displays include virtual anatomical models that have volumetric effect when observed from the viewing screen with the aid of special eye wear. The most common form is stereoscopic 3D video or 3D images popularized in neurosurgical anatomy by Albert J. Rhoton, who utilized 3D stereoscopic images and videos to supplement both academic papers and lectures [15, 16]. The way to generate these stereoscopic images and videos is to use double lens camera or one camera taking photographs from different angles and post-processing these images in a specific way.
Nowadays with innovations of computer equipment driven mainly by gaming industry and 3D graphics has introduced much more advanced technology in the form of VR and AR. Virtual reality (VR) involves the immersion of the viewer completely in a digital environment through special headsets while augmented reality (AR) involves the projection of 3D models and animations into real space whereby the viewer can move freely around the models. [6, 8, 17-20]
All these technological progresses as well as significant improvement of open-source software such as Blender, which is a 3D computer graphics software toolset, which allows for much more user-friendly and comprehensible creation of volumetric 3D models that can be viewed on monoscopic, stereoscopic display or VR/AR environment. Moreover, the advances in web display formats such as WebGL and WebXR technologies allow users to see the generated models from every desktop or mobile devices.
In recent years 3D modeling has become more and more common in the neurosurgery literature in form of anatomy research, education, training and preoperative planning. Giving this trend the demand for high quality 3D models will increase in the future, due to the fact that the workflow of generating such 3D models becomes more and more straightforward and accessible.
Therefore, creating an 3D neuroanatomical atlas is completely possible initiative given the experience of the team behind the project and opportunities presented by the current technological advancements.

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Hypotheses and objectives in order of priority:
(Please provide no more than half a page)

The aim of the project is to create a photorealistic layered and annotated 3D model anatomical collection as well as DICOM CT or MRI based 3D models that illustrate relevant surgical anatomy for cranial and on a second stage spine neurosurgery. There are two main objectives:

- Neurosurgical anatomy
- Neurosurgical approaches

The first objective is to describe relevant neurosurgical anatomy by regions of the cranium and present soft tissue anatomy, neurovascular and bone anatomy. The suboccipital and anterolateral

neck soft tissue anatomy in relation to exposure of the vertebral artery and paracondylar approaches is also planned to be rendered in 3D.
The second objective is to present basic and advanced neurosurgical approaches:

- ***Basic neurosurgical approaches****:* Frontal, fronto-lateral, pterional, temporal, parietal, parasagittal interhemispehric, occipital, median suboccipital, paramedian and retrosigmoid.
- ***Advanced neurosurgical approaches:*** Fronto-orbital (standard, eyebrow, eyelid), fronto-orbito-zygomatic, anterior trans-petrous, retro-labyrinthine, trans-labyrinthine, far lateral

The anatomical dissections of neurosurgical approaches will be further illustrated by 3D volumetric models based on anonymized Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) DICOM data.
The combination of 3D photorealistic anatomical dissections and volumetric 3D anonymized DICOM based models will allow the creation of a large dataset of structured 3D neurosurgery related models.
These 3D models can later be presented on a dedicated web-based 3D platform and can be viewed on any mobile browser, desktop browser, even presented in AR or viewed with VR headset. The other aim of the whole project is to be submitted for publication in a dedicated neurosurgery journal.

Research Plans:
(Please provide no more than two pages)

For the purpose of representative anatomical dissections models, we have prepared structured dissection plan by anatomical regions. Part of the dissections will be done in the Department of Anatomy and Histology, Pathology and Forensic medicine, University Hospital Lozenec, Medical Faculty, Sofia University, Sofia, Bulgaria and another part will be done in Neurosurgical Anatomy laboratory in the Department of Neurosurgery, University Hospital of Düsseldorf, Heinrich Heine University, Düsseldorf, Germany.
We have already started anatomical dissection in University Hospital Lozenec. The first dissection comprised layered anatomy of the muscles of the back and basic osteology of the skull and spine. Another anatomical region which was rendered in 3D was the fronto-temporal region.
Further dissections will be done in Neurosurgical Anatomy laboratory in the Department of Neurosurgery, University Hospital of Düsseldorf which are planned for May.2022. The topic is anatomy of the anterolateral upper neck region with surgical exposures to jugular foramen and V2-V3 segment of the vertebral artery.
For these specific dissections, If possible, the anatomical specimens could be CT scanned before the dissection in order to obtain pre-dissection 3D model of the head. This CT data can be used to plan a neuronavigation station which would be very valuable for the temporal bone drilling in order to achieve representative dissections of the jugular foramen and all the important structures within the temporal bone that are relative to the surgical exposure – sigmoid sinus, presigmoid dural space, labyrinthine block, Fallopian canal with the facial nerve, chorda tympany, jugular bulb.

Further dissections are planned for the rest of the year with the aim of 3D photorealistic volumetric rendering of other basic and advanced neurosurgical approaches as presented above in the section “Hypotheses and objectives in order of priority”

Each step of the dissection will be photographed from multiple angles using high megapixel DSLR camera for the purpose of photogrammetry process of creation of 3D models from the dissections. The photographs will be further processed with dedicated photogrammetry software (Metashape of Reality Capture). The high-quality microscope camera provided in the Neurosurgical Anatomy laboratory, University of Düsseldorf will be used to create intradural 3D photogrammetry models of the approaches.
The 3D photogrammetry scans will be exported to Blender software (https://www.blender.org) for further processing. The end 3D models will be exported to Sketchfab platform (https://sketchfab.com). This is a platform created to publish, share, discover 3D, VR and AR content. It provides a viewer based on the WebGL and WebXR technologies that allows users to display 3D models on the web, to be viewed on any mobile browser, desktop browser or Virtual Reality headset. Another option is that all these models can be additionally exported as separate files and viewed in AR on any modern phone or tablet, or in VR using head mounted device (VR headset compatible with mobile phone, Microsoft HoloLens etc.)

The neurosurgical approaches will be further illustrated by CT and MRI based 3D volumetric models based on anonymized Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) DICOM data. These 3D models will be based on actual clinical cases including intracranial aneurysm clipping, reconstruction after craniofacial trauma, neuro-oncology cases etc.
These 3D models and the anatomical dissection models will add to the educational potential of this atlas platform.

We plan to create a dedicated web page of the project where all the structured dissections and the CT and MRI based 3D volumetric models will be presented. The main platform to host the 3D models will be Sketchfab, which has all the is dedicated to display 3D models on the web.

Team and Scientific Potential:
(Please provide no more than one page)

The scientific team is composed from specialist in different fields of medicine - experienced skull base and neurovascular surgeons, anatomist, and radiology specialist.

- Toma Spiriev has extensive experience in 3D modelling and simulation of neurosurgical approaches based on CT and MRI data, which was his PhD thesis. The technique for preoperative planning and craniotomy simulation (for basic and complex approaches) was applied in more than 230 cranial cases. He also has experience using professional 3D software such as Blender and the technology of photogrammetry used in the creation of photorealistic 3D models
- Priv. Doc. Vladimir Nakov has extensive experience in skull base and neurovascular neurosurgery. We believe that intraoperative photogrammetry-based 3D models as well as preoperative and postoperative 3D models of cases operated by him and our team will

be very informative for the neurosurgeon in training regarding the choice of approach for aneurysm clipping and the modality of clipping technique. We already started to create a 3D collection of aneurysm cases presented in the "Recent publication" section of this document.

- Prof. Jan Cornelius has extensive experience in skull base and neurovascular neurosurgery. We believe that intraoperative photogrammetry-based 3D models as well as preoperative and postoperative 3D models of cases operated by him and his team will be also very informative for the neurosurgeon in training regarding the choice of approach skull base tumor resection, AVM removal technique, aneurysm clipping technique.
- Prof. Galina Kirova is radiologist and Chair of Radiology Department at Acibadem City Clinic University Hospital Tokuda Sofia. Prof Kirova is with 30 years of experience and extensive knowledge of imaging and diagnostic procedures, skilled in operating different types of radiology equipment. Prof. Kirova and her team will be involved in the segmentation of CT and MRI DICOM data which will significantly facilitate the creation of 3D models.
- Priv. Doc Ivan Maslarsky is anatomist, Head of Department of Anatomy and Histology, Pathology and Forensic medicine, University Hospital Lozenec, Sofia Bulgaria. He has extensive experience in teaching anatomy and neuroanatomy, his team is active part of this project for the already rendered 3D photogrammetry models (Please see the "Recent publication" section of this document.)

Apart of from the participants listed in this application we work also with neurosurgeon/medical artist with advanced skills in Adobe photoshop and Adobe illustrator, as well neurosurgeon specialist in intraoperative electrophysiology, functional brain mapping, who has skills in volumetric rendering of brain tractography using Slicer software and brain segmentation from MRI.

We believe that this expertise will be sufficient for the development of such project.

Ethics and Research Governance: ***(for clinical projects only)***
(Please provide no more than half a page)

The project has already passed ethical board approval – protocol number……… from ………
The project was presented before the ethical committee of Acibadem CityClinic University Hospital Tokuda, Sofia, Bulgaria because one key component of the project is anonymized Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) DICOM data from routine radiology examinations that are planned to be used. This anonymized data will be a base for 3D volumetric models rendering, presenting various neurosurgical approaches and help illustrate neurosurgical anatomy.
As the patient data is anonymized and the 3D models are highly processed by 3D software, the patient identity cannot be disclosed.

Patient and Public Involvement:
(Please provide no more than half a page)

There will be no public involvement planned. There will be no patient recruitment planned

Communication Plan for Dissemination:
(Please provide no more than half a page)

The plan for dissemination of our work includes:

- Preparation of a paper manuscript (one or several) that will be submitted to Brain & Spine, The Official Scientific Journal Of Eurospine And EANS, as well as other dedicated neurosurgical journals.
- Development of a dedicated website for the purpose of the Atlas presentation and organization of the 3D models collections.
- Dissemination trough EANS Young Neurosurgeons committee (Toma Spiriev is a member of this committee) and potentially trough the EANS website.
- Social media dissemination
- Official websites of the three involved institutions (University of Düsseldorf, Sofia University, Acibadem CityClinic University Hospital Tokuda)

Outputs: Impact, potential beneficiaries and added value:
(Please provide no more than half a page)

This project can be classified as mixture of classical anatomical and surgical knowledge and modern technology of visualization. We believe that such project would be very promising and would prove the use of this emerging technology in the field of neurosurgery (photogrammetry based photorealistic 3D models) for the purpose of education and training and open the field for further research in the future.
One of the best ways to study anatomy is not only from classical 2D atlases, but from actual dissection work where one can see the spatial relationships of different anatomical structures and have better understanding of these Now, in the recent COVID era access to proper anatomical training is still limited and online resources of education become more and more important.
If such atlas is to be developed and supported by the EANS, the 3D anatomical models will be accessible through every desktop and mobile device with the help of WebGL and WebXR technologies that allows users to display 3D models on the web. Moreover, every model will be available in AR format for IOS and Android phones as well as VR technology for more immersive experience (VR phone based stereoscopic headset, Microsoft Hololens, Oculus quest etc.)
All these 3D modalities allow medical students, neurosurgery residents and neurosurgeons, neuroanatomists to be able to see basic anatomy and complex anatomy such as the one for example of temporal bone, jugular foramen, soft tissue layers of the suboccipital muscles, parasellar neurovascular structures, Sylvian fissure and insular region, from every possible angle, layer by layer, rotate, pan and zoom the 3D models, follow spatially the course of every structure of interest (muscles, vessels, nerves, bones) and perceive understanding of these anatomical relationships.

JUSTIFICATION OF EXPENDITURE	
Details:	**Rationale of the costs:** The recourses needed for such project can be divided in hardware, software, hosting and subscriptions services, project travel expenses, project dissemination costs. Photogrammetry as well as 3D modelling and 3D rendering are very resource consuming processes in terms of computation power and processing time. Therefore, we will need a powerful workstation to be able to render the 3D models and animations at a reasonable amount of time. We already have part of the hardware required for photogrammetry - satisfactory laptop computer, 8 and 12 megapixel DSLR camera and basic VR set). However, for the purpose of 3D neurosurgical atlas, requiring even higher quality photographs and therefore more computing power, we would like to create a dedicated 3D laboratory with workstation computer (PC or MAC based) that can be accessible via remote connection. By this way after photographing the anatomical specimens in the anatomical lab (in Bulgaria or in Germany) the photographs can be transferred remotely to the workstation and rendered to create a 3D model. Moreover, 3D animations that are the most computer resource consuming can be rendered remotely. For the purpose of AR and VR models visualization we would need additional equipment, listed below. We plan to connect this workstation to a high-quality 3D printer (which we already have) and develop further this technology and our 3D models. **Project dissemination costs:** In order present our work we are planning to submit a manuscript to Brain & Spine journal and possibly other dedicated neurosurgery journals. We are planning to present our work on the yearly EANS congress in Belgrade 2022.

	Projected expenses*: ➢ Brain & Spine journal article processing fee **1780 €** ➢ PC or Mac based workstation – 2000-**4000 €** ➢ VR headset **800-1000 €** ➢ Ipad pro (AR features and LIDAR scanner) **800-1000 €** ➢ 24 Megapixel camera -**1000 €** ➢ Studio lighting set – **240 €** ➢ Metashape phtogrammetry software – **160 € one time purchase** ➢ Sketchfab premium account - **160€** yearly subscription ➢ Website hosting – **app. 100 € a year** ➢ Travel expenses (several anatomical dissections in foreign Universities) – **2000 €** ➢ 2022 EANS congress participation fee **750€** *All these parameters are preliminary and can be optimized, depending on the financial support
Total Resource Requested:	➢ 9200-10000€

4. CO-APPLICANTS	
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5. RECENT PUBLICATIONS

I. Photogrammetry based anatomy dissection 3D models:

- Bone anatomy: https://skfb.ly:/osoTM
- Anterolateral neck dissection: https://skfb.ly/o88Pp
- Superficial muscle anatomy of the back: https://skfb.ly/o8ZCI
- Fronto-temporal region bone anatomy (surgical exposure after interfascial temporalis muscle dissection, which is reflected inferiorly and posterior): https://skfb.ly/or8MI

II. DICOM radiology data based 3D models:

- Basilar Invagination: https://skfb.ly/orYzn
- Giant basilar trunk aneurysm: https://skfb.ly/orUHX
- Preoperative large Acom aneurysm: https://skfb.ly/orVZM
- Postoperative large Acom aneurysm clipped trough fronto-orbtital craniotomy:
- Brain vessels anatomy: https://skfb.ly/os9Uv
- Complex craniofacial trauma: https://skfb.ly/os9UA

III. Intra-operative 3D reconstruction trough microscope camera - Right Pcom aneurysm clipping: https://skfb.ly/o8rQO

Previous anatomy dissection experience and finished anatomical projects

I. Completed Anatomical Projects

1. University of Barcelona, Spain. Department of Human Anatomy and Embryology. Project: *Trans-orbital approaches to the cavernous sinus posterior and infratemporal fossa.*

Related Publication:

- Laleva L, Spiriev T, Dallan I, Prats-Galino A, Catapano G, Nakov V, de Notaris M. Pure Endoscopic Lateral Orbitotomy Approach to the Cavernous Sinus, Posterior, and Infratemporal Fossae: Anatomic Study. J Neurol Surg B Skull Base. 2019 Jun;80(3):295-305. doi: 10.1055/s-0038-1669937. Epub 2018 Sep 6.

2. Tuebingen University. Department of Anatomy; Neurosurgery Clinic.

Project: The anatomy of the fronto-temporal branch of the facial nerve

Related publication:

- Spiriev T, Ebner F, Hirt B, Shiozawa T, Gleiser C, Tatagiba M, Herlan S.Fronto-temporal branch of facial nerve within the interfascial fat pad: is the interfascial dissection really safe? Acta Neurochir (Wien). 2016 Mar;158(3):527-32. doi: 10.1007/s00701-016-2711-x. Epub 2016 Jan 23.

3. Copenhagen University. Neurosurgery Clinic. Project: Techniques of preservation of the fronto-temporal branch of facial nerve during orbitozygomatic approaches. One Piece Orbitozygomatic Approach Based on the Sphenoid Keyhole

Related Publication:

- Spiriev T, Poulsgaard L, Fugleholm K. One Piece Orbitozygomatic Approach Based on the Sphenoid Keyhole: Anatomical Study J Neurol Surg B Skull Base. J Neurol Surg B Skull Base. 2016 Jun;77(3):199-206. doi: 10.1055/s-0035-1564590. Epub 2015 Oct 8.
- Spiriev T, Poulsgaard L, Fugleholm K. Techniques for Preservation of the Frontotemporal Branch of Facial Nerve during Orbitozygomatic Approaches. J Neurol Surg B Skull Base. 2015 Jun;76 (3):189-94. doi: 10.1055/s-0034-1396599. Epub 2014 Dec 24.

Previous publications related to 3D modelling in neurosurgery

I. Original Papers

1. **Spiriev** T, Nakov V, Laleva L, Tzekov C. OsiriX software as a preoperative planning tool in cranial neurosurgery: A step-by-step guide for neurosurgical residents. Surg Neurol Int. 2017 Oct 10;8:241. doi: 10.4103/sni.sni_419_16. eCollection 2017. Review.
2. Nakov V, Spiriev T, Todorov I Simeonov P Technical nuances of subtemporal approach for the treatment of basilar tip aneurysm. Surg Neurol Int. 2017 Feb 6;8:15. doi: 10.4103/2152-7806.199555. eCollection 2017
3. Nakov V, **Spiriev** T, Stavrev E How I do it: surgical clipping of vertebrobasilar junction aneurysms through a far-lateral transcondylar approach.. Acta Neurochir (Wien). 2018 Jun;160(6):1149-1153. doi: 10.1007/s00701-018-3512-1. Epub 2018 Mar 14.
4. T. Spiriev, L. Laleva, M. Milev, D. Ferdinandov, Chr. Tzekov, V. Nakov, **Systematic literature review regarding the measurement accuracy with software for 3D visualization and preoperative planning OsiriX and Horos.** Bulg Neurosurg, 2018, 23 (1-2) (*in Bulgarian*)
5. Spiriev T, Milev M, Stoyanov S, Laleva L, Plachkov I, Staneva M, Nakov V. A rare case of carotid body tumor associated with near complete cerebral sinus thrombosis and idiopathic intracranial hypertension. Management strategy and review of the literature. Surg Neurol Int 2021 Jun 7;12:262. doi: 10.25259/SNI_170_2021.

II. Congress participations

1. L. Laleva, T. Spiriev, M. Milev, V. Stefanov, N. Mladenov, M. de Notaris, C. Tzekov, V. Nakov **Minimally invasive lateral orbital approach for clipping of intracranial aneurysm in the acute stage after subarachnoid bleeding** Proceedings of the EANS congress October 2018, Brussels, Belgium
2. *Toma Spiriev, Lili Laleva, Vladimir Nakov, Nikolai Gergelchev, Christo Tzekov* Preoperative planning, simulation of cranial approaches and operative perspective in intracranial aneurysm surgery using OsiriX software. Results in 25 cases Proceedings of the EANS October 2017, Venice, Italy
3. *T. Spiriev, L. Laleva, Matteo de Notaris* Pure endoscopic lateral orbitotomy approach - Intra- and extradural limitations. Anatomic study Proceedings of the EANS October 2017, Venice, Italy
4. Spiriev T, Laleva L, Nakov V, Gergelchev N, Tzekov Chr. Osirix software for preoperative planning of skull base and supratentorial meningioma surgery Proceedings Of The National Conference Of Neurosurgery – October 2016, Velingrad, Bulgaria
5. L. Laleva, M. de Notaris, T. Spiriev, A. Di Somma, E. d'Avella, A. Prats-Galino, G. Catapano Freehand dynamic endoscopic lateral orbital approach to the

cavernous sinus. Anatomic study; Proceedings of the EANS congress 18-21 October 2015, Madrid, Spain

6. T. Spiriev, M. de Notaris, L. Laleva, D. Di Maria, G. Catapano The use of 3D virtual endoscopy for the surgical planning in endoscopic spontaneous cerebrospinal fluid leak repair; Proceedings of the EANS congress 18-21 October 2015, Madrid, Spain
7. T. Spiriev, L. Poulsgaard, K. Fugleholm Quantative measurements of the sphenoid ridge using anatomical and 3D modeling studies and its relevance to the MacCarty and Sphenoid ridge keyholes; Proceedings of the EANS congress 18-21 October 2015, Madrid, Spain
8. T. Spiriev, F. Ebner, T. Naegele, M. Tatagiba Simulation Of Cranial Neurosurgical Approaches Using Osirix Software Proceedings of the EANS congress 11-14 October, Prague, Czech republic
9. T. Spiriev, M. Tatagiba, T. Naegele, F. Ebner Preoperative Visualization Of Neurovascular Conflict Using 3-D Constructive Interference In Steady State Based Reconstructions In Osirix; Proceedings of the EANS congress 11-14 October, Prague, Czech republic